THE EFFECT OF A STICKHANDLING AND PUCK CONTROL (SPC) TRAINING INTERVENTION ON SPC SKILLS AND WRIST SHOT PERFORMANCE VARIABLES IN FEMALE COLLEGIATE ICE HOCKEY PLAYERS

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ABSTRACT

The purpose of the study was to investigate the effect of a 16 session stickhandling and puck control (SPC) off-ice training intervention on SPC skills and wrist shot performance variables. Eighteen female collegiate ice hockey players participated in a crossover design training intervention, whereby players were randomly assigned to two groups. Each group completed 16 SPC training sessions in two conditions [normal vision (NV) and restricted vision (RV)]. Measures obtained after the training intervention revealed significant improvements in SPC skills and wrist shot accuracy. Order of training condition did not reach significance, meaning that SPC improvement occurred as a result of total training volume as opposed to order of training condition. However, overall changes in the RV-NV condition revealed consistently higher effect sizes, meaning a greater improvement in performance. Therefore, support can be provided for this technical approach to SPC training and an alternative method of challenging SPC skills.

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CHAPTER 1: INTRODUCTION

Shooting, stickhandling and puck control (SSP) are fundamental skills in both the men's and women's game of ice hockey. Although scoring is identified as the ultimate performance factor; the fundamental skills of stickhandling and puck control (SPC) are necessary, as players must maneuver the stick and transport the puck successfully past and through opponent obstacles to gain access to the net. SSP studies have traditionally focused on the biomechanics of shooting (Hayes, 1965; Doré & Roy, 1973; Naud & Holt, 1975; Roy & Doré, 1976; Polano, 2003; Woo, 2004; Lomond, 2005; Villaseñor, Turcotte & Pearsall, 2006), the effects of strength training on shooting abilities (Alexander, Drake, Reichenbach & Haddow, 1964; Pan, Campbell, Richards, Bartlolzzi, Ciccotti, Snyder-Mackler & Waninger, 1998; Fergenbaum & Marino, 2004), and the effects of equipment design on shooting abilities (Alexander, Haddow & Shultz, 1963; Nazar, 1971; Rothsching,1997; Marino,1998; Leiter, 2001; Wu, 2002; Marino & Cort, 2004; Simard, Roy, Martin, Cantin, & Therrien, 2004; Worobets, Fairbairn & Stefanyshyn, 2006; Gilenstam, Henriksson-Larsén, & Thorsen, 2009), with unequivocal attention to how the athlete handles the puck in order to optimize scoring opportunities. Unlike dedicated shooting clinics and practices, stickhandling and puck control are often left to be acquired through repetition and game play.

To the knowledge of this author, research conducted on how to train SSP skills is limited to practitioners' articles and a single research study (Stark, Tvoric, Walker, Noonan & Sibla, 2009). Furthermore, SSP literature has focused predominantly on male-hockey athletes with limited representation of the female game, despite the fact that, the female game is often criticized for the underdevelopment of hockey-related skills. Leiter (2001) reported that, there is a large variation of shooting and stickhandling skills between males and females at all age levels. An analysis of collegiate women's hockey scoring statistics completed during the 2007-2008 season (www.universitysport.ca) reported low scoring rates in women (Table 1). In comparison to the men, men produced approximately twice the number of goals in the same season of games (Table 2). It could be proposed that varying degrees of skill among genders is a result of the type of game play. The main difference between the men's and women's game is the intentional use of body contact resulting in a more 'heads up' type of game. A 'heads up' focus could potentially take the athlete's focus away from the puck and encourage kinesthetic awareness or an intuitive feel of stickhandling and puck control leading to creativity of play and target selections. The question of whether a more 'heads up' type of game develops SPC abilities has yet to be determined. Furthermore, SPC skills, or the lack thereof, might be a factor that has significantly influenced scoring statistics in the women's game.

Therefore the primary purpose of this study was to investigate the effect of a 16 session stickhandling and puck control (SPC) training intervention on 4 puck control variables: simple and complex stickhandling scores and the transfer of training to 3 wrist shot performance variables. A secondary purpose was to examine the effect of order of two specific training conditions (restricted vision-normal vision [RV-NV] vs. normal vision-restricted vision [NV-RV] SPC training) on the same seven variables.

1.1 Purpose of the Study

1. To determine the effect of a sixteen session SPC training intervention on stickhandling and puck control variables (simple and complex) and whether this type of off-ice SPC training transferred to 3 wrist shot performance variables: shot speed (mph), release time (seconds) and shot accuracy (percentage/targets hit).
2. To determine if the order of SPC training (NV-RV or RV-NV) conditions received significantly affected the same variables.

1.2 Null and Alternative Hypotheses

A two tailed, non directional hypothesis was used indicating that there would be no effect on SPC scores, grip strength, shooting speed, release and accuracy as a result of the 16 SPC training sessions. It was anticipated that no significant difference in SPC scores would occur as a result of the sequence of SPC training conditions.

SPC and Shooting Variables:

$$H_0 = M_{PRE} = M_{POST2}$$

$$H_1 = M_{PRE} \neq M_{POST2}$$

Between Training Conditions:

$$H_0 = M_{NV\text{-}RV} = M_{RV\text{-}NV}$$

$$H_1 = M_{NV\text{-}RV} \neq M_{RV\text{-}NV}$$

1.3 Significance of Study

Limited research has been published detailing how to effectively assess or train SPC skills. This study provides fundamental stickhandling research and also utilizes female university players; a demographic that has received limited research attention.

Secondary to the study's primary purpose, the study aimed to identify if there was any transference of SPC skill training to shooting performance in a simulated setting.

CHAPTER 2: LITERATURE REVIEW

2.1 Hockey Skills

The sport of ice hockey is a skill orientated game which requires the technical skills of skating, shooting/scoring, checking, stickhandling and passing. Shooting, stickhandling and puck control are fundamental skills in both the men's and women's game of ice hockey. The performance demands of shooting rely on a combination of the physical (strength), mechanical (technique) and mental (shot selection and proper target) abilities to achieve optimal success in goal scoring. Developing the ability to score goals may be more natural for some players, however it could be suggested that these players have both greater puck possession abilities and are able to manipulate the puck better on the ice, thus questioning the influence of fundamental SPC skills on game performance. Several studies examining development of ice hockey players have investigated shooting/scoring statistics (Renger, 1994; Montgomery, Nobes and Pearsall, 2004), shooting training interventions (Alexander, Drake, Reichenbach & Haddow, 1964; Pan, Campbell, Richards, Bartlolzzi, Ciccotti, Snyder-Mackler & Waninger, 1998; Fergenbaum & Marino, 2004), shooting performance analyses (Hayes, 1965; Cotton, 1966; Nazar, 1971; Doré & Roy, 1973; Naud & Holt, 1975; Roy & Doré, 1976; Hoerner, 1989; Rothsching, 1997; Leiter, 2001; Wu, 2002; Polano, 2003; Woo, 2004; Lomond, 2005; Villaseñor, Turcotte & Pearsall, 2006**;** Michaud-Paquette & Pearsall, 2009) and stickhandling training (Stark, Tvoric, Walker, Noonan, Sibla, 2009). There has been limited literature comparing hockey skills such as shooting skills between genders (Wu, 2002) however a greater emphasis has been placed between skill levels during shooting (Alexander, Haddow & Shultz, 1963; Roy and Doré, 1976; Wu. 2002; Woo, 2004;

Lomond, 2005; Villaseñor, Turcotte & Pearsall, 2006). Additionally, a commonality amongst the literature is also the lack of research conducted on female game in comparison to males. Although it is recognized that the some skills are specific to position (Renger, 1994; Montgomery, Nobes and Turcotte, 2004), stickhandling in general is a skill component that is important for both the positions of forward and defence (Renger, 1994) and that development programs should be created and trained accordingly.

2.1.1 Training of Hockey Skills

Stickhandling and Puck Control Training Methodologies

Research examining stickhandling methodologies is scarce despite the importance of these skills during game action. The majority of literature dedicated to stickhandling and puck control has been practitioner based, focusing on teaching methodologies of professional players or trainers with an experienced background. Merrifield and Walford (1969) developed 6 tests for a battery of ice hockey skills which included forward and backwards skating, skating agility, puck carry, shooting and passing. Four (forward, backwards, agility and puck carry) of the six tests were reliable, with the puck carry test being determined as the best single predictor for overall ability. The puck carry test was found to have significant relationships to each of the other 3 tests (forward skating speed ($r = .78$, $p \leq .05$), backwards skating speed ($r = .71$, $p \leq .01$) and skating agility ($r = .74$, $p \leq .01$), however no technical analysis/training was involved.

Leavitt (1979) examined the cognitive demands of skating and stickhandling tasks of novice to varsity male hockey players. The dual task performance consisted of the primary task of skating and secondary tasks of identifying objects (perceptual task) and or stickhandling (response task). Leavitt found that skating became automatic while performing the secondary tasks (stickhandling/identifying) after the player had approximately 8 years of experience. The younger, less experienced produced significantly more stickhandling errors when having to simultaneously identify objects compared to stickhandling only test, suggesting that perceptual processes were favored over the response processes.

A study conducted by Stark, Tvoric, Walker, Noonan & Sibla (2009), involved on-ice stickhandling training for 10-15 minutes using a weighted puck using both experimental and control groups. The subjects ranged from 12 to 14 years and included some female subjects. Stickhandling ability was tested by having the subjects skate through an obstacle course using a normal weighted puck as described here: “Started from a stopped position, controlling the puck while reaching wide to the left and right, controlling the puck through a tight and fast obstacle region and performing a figure eight around obstacles with a puck” (p.55). This obstacle course was much more complex than the courses utilized by Merrifield and Walford, 1969; Leavitt, 1979 and Leiter, 2001, which were straight out and back courses with 6-7 obstacles to assess stickhandling and puck control abilities. The stickhandling training included 2 weeks of: power/strength drills, endurance drills followed by speed drills. Results showed that by overloading the sport specific movement of stickhandling by using a weighted puck and through the use of different stickhandling drills, player’s enhanced grip strength endurance and stickhandling abilities. Both the Leavitt and the Stark et al. study were conducted on-ice and involved players/participants between the ages of 7 - 14years of age.

Practitioners' articles or "how to" related articles are proliferate. These articles have detailed information for improving stickhandling using methodologies such as: practicing stationary, while moving, using obstacles, light balls for developing quick hands, weighted pucks/balls for improving the strength of the stickhandling muscles, or utilizing commercially available products to develop stickhandling. These additionally highlight tips for players to focus on such as cupping the puck which involves(rolling wrists) to help reduce slapping the puck, altering hand positions, coordination of the feet, stick, eyes and hands. Several instructional hockey videos have been developed with stickhandling strategies integrated; however mainly encompass all hockey skills, with stickhandling sections having minimal coverage. Sean Skinner (2003), has produced an instructional ice hockey video series, with one pertaining specifically to off- ice stickhandling methodologies. Skinner (2003) identified that vibration is also a resource used to track puck location. When the puck taps the stick blade, a vibration is sent up the shaft so that the player can feel where the puck is on the blade. The closer the puck or ball is to the toe of the blade, the weaker vibration, whereas the heel of the blade will give a stronger vibration (Figure 1). Skinner (2003) also suggests drills should be 20-30 seconds in duration with 2 or 3 sets. These drills consisted of moving the ball or puck around the body; completing multiple tasks requiring additional attention and advanced movements for the more skilled stickhandlers. When these skills should be implemented into training programs for player development and proper progressions have yet to be determined.

Shooting and Stickhandling Surface

The game of ice hockey is played on ice, however when training off –ice, an alternative method to simulate a low friction surface is required. The low friction interactions of the ice and puck or blade, is partially due to a quasi-fluid water layer, acting as a lubricant allowing the ice to be “slippery” (Haché, 2002). In several laboratory studies on ice hockey, a polyethylene surface is used to closely mimic the low coefficient of friction of real ice, while being able to perform tasks in a laboratory setting (Lomond, 2005; Pearsall, Rothsching, 1997; Simard, Roy, Martin et al., 2004; Villaseñor et al., 2006; Worobets, Fairbairn & Stefanyshyn, 2006; Woo, 2004; Wu, 2002; Michaud-Paquette, Pearsall & Turcotte, 2009).

2.1.2 Stickhandling and Shooting Technique

The hockey stick is an important factor as it is the link between the player and the puck. The precise amount of wrist/forearm flexion/extension and pronation/supination involved in shooting is unknown; however this exact movement is also involved during stickhandling and puck control. There are several similarities between the movements of stickhandling and the wrist shot such as the amount of continual puck contact with the blade during basic stickhandling movements, the longer duration of puck-blade contact time during the preparatory phase of the wrist shot and how players often utilize several stickhandling repetitions prior to puck release to properly position the puck on the blade. The player’s ability to manipulate blade orientations during stickhandling as well as using constant blade orientation manipulations to open and close the blade face and or draw the puck closer or further away from the body utilize same distal movements of the forearm and wrist as seen during the snapping motion of the wrist shot. Determining and training the interactions of the player, stick and the forearm/wrist movements of stickhandling and or shooting has not yet been investigated.

The importance of the arms and wrists during stickhandling motions, is similar to the motions in a wrist shot, as in many instances, pushes/ pulls with the puck requires the same combination of wrist/forearm flexion/extension supination and pronation. With respect to the wrist shot, Haché stated “because the puck is in contact with the blade for a longer period, it is easily guided into the proper direction with a flick of the wrist” (p. 90, 2002[b]). Having longer blade-puck contact times during the wrist shot suggests the importance of the interaction between the blade, puck and player, such that it should be an integral piece included for analysis. Specifically, Michaud-Paquette, Pearsall & Turcotte (2009) found puck-blade contact times between ~150-170 ms for the bottom corners and ~180 ms for the top corners of the goal. Not only does the amount of time on the blade potentially contribute, but also where on the blade the puck is located. The same study found that the strongest accuracy predictor for bottom targets was the position of the puck on the blade such that higher caliber players positioned the puck approximately 18cm from the heel, whereas lower caliber players positioned it closer to the heel. Similarly, Lomond’s 2005 blade study found that the loft angle of the blade resulted in significant differences between the skilled and unskilled players, such that the skilled players utilized a more closed face of blade before opening up and therefore had a greater overall loft range (13° vs. 6°). Lomond made the suggestion that the opening/closing of the blade’s face is due to the increased rolling of the wrists (combination of flexion/extension and pronation/supination). The relationship between stick blade movements and forearm pronation/supination was also suggested by Leiter

(2001) when investigating the wrist shot. The blade's angular displacements and velocities were used to estimate the amount of forearm pronation of the dominant hand on the stick, suggesting that any blade rotation in transverse plane is due to forearm pronation. Expanding this point further, the importance of the wrist snap motion has been consistent throughout the literature. Even from the earliest of literature Hayes (1965) identifies:

> At the moment of impact, the wrists snap, i.e., top wrist into extension and lower wrist into flexion from supination and pronation respectively. This culminates the velocity build up. The arms are now extended and the wrists rolled as in the baseball swing. (p.31)

For most shots, the literature emphasizes the action of the forearm/wrists during the final moments during the shot such that it a critical factor/point for the shot. This is also supported by Lomond (2005), which showed both elite and recreational players begin to close their blade near puck contact, however at puck contact, elite displayed significantly smaller angle then the recreational players, suggesting that the elite group was able to accomplish a greater wrist snap than the lower skilled group.

2.1.3 Shooting Speed and Accuracy

Both physiological and biomechanical research conducted on shooting has primarily focused on the slap and wrist shots, again with emphasis on the male athlete. Only Leiter (2001) and Wu (2002) have examined the female wrist shot and Gilenstam, Henriksson-Larsén & Thorsen (2009) who investigated the female slap shot. Leiter's 2001 wrist shot study found no significant differences in either puck velocity or wrist shot technique for the different puck weights of elite female players, however trends were suggestive of greater puck velocities with lighter pucks. Of significance, the players having greater wrist shot velocities produced greater linear displacement of centre of gravity as well as greater angular displacements and velocities of the trunk, shoulders and stick blade. Leiter suggested skilled players have the ability to transfer the high body segment velocities and the linear center of gravity displacement to the puck. Amongst the literature, one of the most consistent findings was how strength plays a role; however shooting is very player dependent, such that skill/technique/experience and that neuromuscular coordination may also play a large contributing role towards increased shooting velocity (Alexander et al., 1963; Moyls, 1981; Wu, 2002; Fergenbaum and Marino, 2004). Furthermore, it is also the way in which the player interacts with the stick (ie. how player decides to apply load) which seems to be influential towards puck velocity, especially over variables such as stick construction, maximal forces applied (Alexander, Drake, Reichenbach & Haddow, 1964; Doré and Roy, 1973; Rothsching 1997; Wu, 2002; Worobets, Fairbairn & Stefanyshyn, 2006).

Despite the common notion as stated in Alexander et al., 1963, that "in the opinion of many hockey coaches, a player's speed of shooting is directly related to his wrist strength," the majority of previous literature (Alexander et al., 1963; Nazar, 1971; Roy and Doré, 1976) has found low positive correlations between grip strength and shooting velocity. Whereas Wu (2002) found significant moderate positive correlations between wrist shot velocity and grip strength (right grip r = .66; left grip r = .61). Through previous static strength and movement research as cited in Alexander et al. (1963), it was suggested that the low correlations were present because the strength of gripping the stick during shooting may be different then during a static grip test. Moyls (1981) also found that wrist strength variables were not as important for shooting velocity; however the authors suggested that forearm supination and pronation may be more important than wrist flexion, extension or grip strength. A range of wrist shot velocities of both genders are detailed in Appendix B.

Regardless of the professional opinions of NHL scouts indicating shooting accuracy weighted/ranked the highest for both forwards and defense among shooting/scoring variables (Renger, 1994), literature examining factors influencing shot accuracy has not been extensive. Table 3 outlines the distances/target locations previously used to assess accuracy itself or for biomechanical analysis. Previous findings regarding shot accuracy resulted with the standing slap shot and skating wrist shot being the least and most accurate shots respectively (Alexander et al., 1963). Curved blades are more accurate then straight blades for both the wrist and slap shots (Nazar, 1971) and that lighter puck weights have no effect on wrist shot accuracy (Leiter, 2001). Recently, a very relevant study by Michaud-Paquette, Pearsall & Turcotte (2009) identified significant technique variables which were most related to wrist shot accuracy. Several release characteristics (puck release orientation and velocity), shaft bending and the change in blade orientations greatly contributed towards accuracy. Although not seen through visual observation, blade orientation angles were very different amongst the high and low caliber players. Secondly, there were significant differences found between top and bottom goal corners, with the top corners correlating higher with accuracy (r = 0.90-0.92) than the bottom corners (r = 0.72- 0.82). The blade's heel velocity and puck-blade position were most influential for bottom corners whereas blade heel velocity, puck linear velocity, changes in the blade yaw angle and maximum shaft bend were most influential for the top corners. Additionally, the blade's roll angle at release (β_r) and the change in yaw angle ($\Delta\Psi$) were good top corner predictors. Both of these characteristics are directly related to the player's ability to have better player-puck-stick/blade awareness. This ability was demonstrated by the high caliber players as they would consistently drag or draw in the puck closer to body during puck contact (β) yet were also capable of moving the puck to an optimal blade position, resulting in greater overall puck guidance. Due to the wrist shot being a non-impact shot, it was suggested that the blade orientation at puck release did not predict shot trajectory, but rather was due to the blade orientation changes throughout puck-blade contact. The puck was guided, steered and cradled throughout the contact phase which allows for proper positioning of the puck on the blade though changes in pitch ($\Delta\phi$) and yaw angles ($\Delta\Psi$).

2.2 Challenge Point Framework

In the sport of ice hockey, the stickhandling blade surface can be altered for different SPC tasks such as using just the toe of blade during the more difficult complex SPC movements versus the simple SPC movements, where the puck has the ability to move along the entire length of the blade (heel to toe). By keeping the blade in its neutral position (side to side), this decreases the amount of potential errors as it is harder to lose control of the puck. Sensory feedback while stickhandling includes, visual, tactile (vibration), auditory (puck on blade; puck sliding on a polyethylene board) and proprioceptive information. To assist in understanding the SPC performances under the different visual training conditions (normal and restricted vision) and for the different difficulties in tasks (simple and complex), concepts from the The Challenge Point Framework are examined.

The Challenge Point Framework (CPF) defines the relationship and interactions of information availability, performer's skill level and motor task difficulty (Guadognoli and Lee, 2004). The large concept of task difficulty was separated into smaller components for its application: nominal difficulty (consistent characteristics of the task) and functional difficulty (how challenging the task is relative to skill level and practice conditions). Simply stated, the authors suggested that as the nominal task difficulty increases (for example more difficult stickhandling drills), performance decreases, and this decline is more pronounced in the lower than higher skilled performers. An easier nominal task reduces the potential of available information for performers of any skill level. When defining functional task difficulty, performers of different skill levels have different capacities for interpreting various practice conditions (for example different visual conditions when training) with the certain degree of nominal task difficulty. This difference results in the amount the performer can learn from the specific situation. A task of greater functional task difficulty creates a larger potential for learning, however is still dependent upon the performer's skill level, how complex the task is and what the training environment consists of (p. 222).

Expanding on these interactions/relationships, the amount of potential information available in situations is a major factor driving this framework. Guadagnoli and Lee used material from information theory and information processing proposing the two critical sources for learning. These two sources, the action plan and feedback, are the means of how information can be transmitted. The action plan is "intentional and results in a specific movement which is used for comparison with the sensory feedback received from the ongoing and completed movement" (Wolpert et al., 2001, as cited in Guadagnoli and Lee, 2004). Feedback therefore “represents information from sources (a) that are inherent to the performer and are normally available during a performance (ie. visual and kinaesthetic feedback) and (b) that might not normally be available to the performer but can be augmented to the performance experience by an extrinsic source” (p.214). Perfectly stated, “as functional difficulty increases, there is less certainty about the potential success of a movement (action plan) and about the potential outcome of the movement (feedback)” (p. 215).

As discussed earlier, the importance of information availability drives the CPF such that high functional difficulty tasks have different responses for both expert and novice performers. As functional task difficulty increases (ie. restricted vision SPC), so too does potential available information. This coincides with the communication theory, which states that information is only transmitted when uncertainty is reduced (p.214).Tasks of high functional difficulty reduce the confidence of the novice performers in their action plan, and regardless of the outcome, the uncertainty received reduces the amount of feedback received. Conversely, in movements deemed of low functional difficulty (ie. normal vision SPC training), expert performers anticipate a flawless performance, thus feedback confirmation is accurate and therefore no information would be produced (p.215). With the combination of the previous components, this framework integrates three main reasons of how performers can use the available information for the potential to learn:

> (a) Learning cannot occur in the absence of information, (b) learning will be retarded in the presence of too much information, and (c) learning achievement depends on an optimal amount of information,

> which differs as a function of the skill level of the individual and the difficulty of the to-be-learned task" (p.213).

As previously mentioned, the importance of information availability is the prerequisite for learning, however, Marteniuk (1976, as cited in Guadagnoli and Lee, 2004), suggested there is a limit to amount of potential information available. This potential is controlled by the performer's capacity to process information, and is subject to change with practice. Marteniuk suggested that practice leads to redundancy, less uncertainty, and, hence to reduced information, and therefore stated, "the more that practice leads to better expectations, the less information there will be to process" (p.215, cited in Guadagnoli and Lee, 2004). The authors also integrate the different types of practice: random and blocked, and how they apply to the various skill levels and performance.

Likewise, for optimal execution, performers need to utilize the greatest amount of information available that properly suits the individual's ability. The authors suggested that in every situation/task, there are hypothetical points (optimal challenge points) which are established and dependent on the performer's skill level, and these represent the optimal amount of potential and interpretable information. Essentially, performers must be challenged (increase functional task difficulty with respect to skill level) in order to improve performance, however, either too much or little information can affect the performer's ability to process/interpret information and therefore potentially decreases the ability to learn and perform. These challenge points must be identified to optimize learning and performance. Lastly, although increasing the functional task difficulty (amount of information increases), has the potential for more information/learning, the amount that is interpretable may not once it reaches a certain point and both learning and performance remain constant or decline.

Therefore the main concepts that can be taken from literature: first, there is a need for research on female hockey players and for the fundamental skill of stickhandling. Second, SPC technique emphasizes the movement of wrist rolling (flexion, extension, pronation and supination) to properly manipulate the puck on the blade of the stick. This requires adequate dexterity depending on the task/drill to allow for proper changes in blade orientations in maintaining puck control. Third, for strictly stickhandling training, approximately 10-15 minutes of multiple drill sets which are 20-30seconds in duration is suggested. The different drills should accommodate different changes in blade orientations. Synthetic ice (polyethylene) can be used as a laboratory alternative to on ice (situation specific). There is a relationship between the skill level, task difficulty and practice conditions that will influence how much the performer can learn to properly optimize performance. Nonetheless, the amount of potential information to be learned must be effectively used via optimal challenge points. By utilizing different nominal and functional difficulties, an additional challenge can be added to the task of stickhandling and puck control by identifying a potential optimal challenge point. Lastly, SPC training may provide a potential contribution to shooting (wrist shot). Both stickhandling and wrist shot mechanics involve the combination of movements during wrist rolling (flexion, extension, supination and pronation). Stickhandling is also a precision task, similar to the shooting accuracy task. Both require knowledge of puck-blade locations and proper control throughout. Stickhandling skills were proven to be good predictors of overall ability; therefore greater skill may lead to having a greater ability to manipulate blade orientations (as seen in elite players) for the potential increase in accuracy as well with improved interaction with ones stick, also which may lead to greater chances at improving ones shooting performance.

CHAPTER 3: METHODOLOGY

The primary purpose of this study was to investigate the effect of a 16 session stickhandling and puck control (SPC) training intervention on four stickhandling and puck control variables and three wrist shot performance variables. The stickhandling and puck control variables consisted of two simple (side to side) and two complex (figure 8) stickhandling drills (reps per 20 seconds). The wrist shot performance variables consisted of shot speed (mph), release time (seconds) and shot accuracy (percentage/number of targets hit). A secondary purpose was to investigate the effect of order of two different training conditions (NV-RV and RV-NV). It was proposed that restricted vision training (RV) would act as an overload stimulus to elicit a training effect.

3.1 Participants

Eighteen female ice hockey players (n= 18) currently playing at the collegiate level were recruited to participate in the study. The study was limited to players in the positions of forward (n= 12) and defense (n= 6). Participant demographics included mean age of 19.67± 1.72 years, mean height of 167.28 ± 5.58 centimeters and a mean weight of 71.21 ± 10.98 kilograms (Table 4). Prior to participation in the study, participants completed an informed consent form and a participant questionnaire investigating player's primary position, shooting handedness, years of hockey experience and hockey levels achieved (Appendix C). Participant questionnaire responses are detailed in Table 5. This project received ethical clearance by the Brock University Research Ethics Board (File # 08-173).

3.2 Study Design

The study was a randomized crossover design conducted to examine the effect of a sixteen session off-ice SPC training intervention on skill development. Participants were randomly assigned to two groups. Both groups received a total of 16 SPC training sessions under two conditions [normal vision (NV) and restricted vision (RV)] however in reverse orders. A battery of tests was completed during week 1, prior to the training (PRE), during week 5, upon completion of 8 training sessions in the first condition (POST1) and during week 9, upon completion of 8 training sessions in the second condition (POST2). Order of condition was sequenced to examine an overload strategy specific to SPC training. With this type of design, each participant served as their own control. The study was scheduled during the second half of the 2008-2009 regular season of play, with both testing and training integrated into the team practice regime over a nine week period (Figure 2).

3.3 Equipment

During all assessment and training sessions, participants wore their team gloves (Christian Torch Gloves, Niagara Falls, ON), a helmet with facemask (Mission Intake, Kirkland, QC) and used a stick of personal preference. Using personal equipment minimized familiarization time and allowed for player comfort. During the RV condition only, the participant’s helmets were retrofit with the facemask screen, designed specifically for the purpose of the study (Figure 3). Participants were not required to wear a helmet during normal vision training or for the shooting assessment. Stickhandling was assessed using a battery of skill drills performed on an individual Puck Pad, also designed for the purpose of the study. The Puck Pad is a 50 x 90 cm rectangle of artificial ice with markings resembling an ice rink surface, providing the subjects with key positioning for the drill patterns during the different SPC tasks (Figure 4). Shooting was assessed using the commercial RapidShot™ hockey training system measuring shot speed (mph), shot release (seconds), and shot accuracy (number of targets hit).

3.4 Testing Sessions

PRE, POST1 and POST2 test batteries consisted of four evaluations: forearm/grip strength assessment, SPC assessment and shooting assessment. A motivational questionnaire was completed POST1 and POST2 to confirm the interest/enjoyment and effort invested in the SPC training. Forearm strength, SPC drills and the questionnaire were all completed on the same day. The shooting assessment was completed on a separate day to best accommodate players schedules. Prior to all testing sessions, participants were required to complete a standardized warm up, consisting of 50 jumping jacks, followed by either a SPC warm up exercises for SPC assessments or dynamic upper body exercises for the shooting assessments. Participants were asked to confirm if they were adequately warmed up; additional individual exercises were performed if required.

3.4.1 Forearm/Grip Strength Assessment Protocol

Forearm/grip strength was assessed using a hand grip dynamometer (Smedley's Dynamometer 100kg, Tokyo, Japan). Participants completed two non-consecutive maximal grip trials for each the left and right hand. The arm was slightly abducted from the body with the dynamometer held in line with the forearm at thigh level and then maximally squeezed, per the grip strength protocol from the *Canadian Physical Activity, Fitness and Lifestyle Approach manual (3rd Ed*).The highest scores of the two trials were recorded and used for analysis (combined hands). All scores were recorded to the nearest 0.5 of a kilogram.

3.4.2 Stickhandling Assessment Protocol

Stickhandling was assessed using six different drills on a Puck Pad. The order of the drills was randomly assigned using a pre-selected sequence of the possible testing conditions of: normal (N), cognitive (C) and restricted (R) for both the simple (side to side) and complex (figure 8) tests. The cognitive test was only used to assess an initial skill level. Detailed descriptions of the Puck Pad assessment drills are outlined in Appendix D. Each SPC test was completed for 20 seconds and the total number of successful repetitions was recorded.

3.4.3 Shooting Assessment Protocol

Shooting assessments were performed using the commercial RapidShot™ hockey training system (Figure 5). This simulated shooting device is highly game specific providing a dynamic pass and random targets. The net was 4 feet by 6 feet (1.22 meters by 1.83 meters) constructed with a steel front frame with a colored target mat (Figure 6). The distance from the net to the shooting surface was equivalent to the area just above the hash marks on the ice surface. Rapid shot pucks used for the purpose of the study are the same dimensions as regulation sized pucks; however are slightly lighter (5 grams) and differ in color. Positioning of the athlete's position for all shot assessments were standardized on the shooting platform of the RapidShot™. The athlete's back foot was aligned with the 1 inch boarder surrounding the shooting platform (Figure 7). The line was used to standardize foot placement ensuring that players shot from the same distances each time, as the release/reaction time was recorded from an infrared beam located in front of the shooter. A familiarization session using the RapidShot™ system was completed before all testing sessions to ensure participant's comfort with assessment system and protocol. This session consisted of 2 non-consecutive rounds of shots (16 shots per round, for a total of 32 familiarization shots). Familiarization also allowed the researcher a test trial to determine the appropriate passing interval and passing speed for the subject group. The passing interval was set at 4.0 seconds between passes and the passing speed was set at a speed of 23 miles per hour (37.02 kilometers per hour), both of which remained consistent for all testing sessions. During the 16 shot series, one of the 4 corner lamps would randomly light up indicating the target to shoot at. Shooting statistics were measured and averaged over the third round of shots (16 shots) and were recorded manually (Appendix E). Appendix F further describes this system in further detail.

3.4.4 Motivational Questionnaire

A twelve question motivational questionnaire was completed at POST1 and POST2 to examine what the participant's experience was like during the SPC training. The questions were comprised of a subset of 2 scales from the intrinsic motivation inventory measurement scale: seven questions from the interest/enjoyment subscale and five questions from the effort subscale (*Intrinsic Motivation Inventory, 2008*), detailed in Appendix G. Each question generated an individual item score which was then averaged within each subscale. The resulting subscale scores were used to confirm the participant's interest/enjoyment and effort during the different training conditions.

3.5 SPC Training Sessions

SPC training sessions were scheduled two to three times per week prior to the participants regular on ice practices with a minimum of 36 hours rest between sessions.

Players used their own sticks and gloves, and performed all drills on an individualized Puck Pad. Each training session was 10 minutes in duration and consisted of a warm up drill followed by five different SPC drills per session (Appendix H). The warm up was 3 minutes in duration and emphasized technique. The drill sets began with simple movements defined as movement in a single plane such as the side to side test task, and then progressed to more complex patterns defined as multidirectional movements such as the figure 8's. The more complex patterns varied from using the toe of the blade and different body positioning around the Puck Pad to utilize the largest range of motion possible. The drills varied in duration depending upon the complexity of the drill. Drills involving direction changes required double the time. A work to rest ratio of 5:1 was consistent throughout all training sessions. During the rest time, a brief demonstration of the next drill was given to ensure proper SPC drill execution. Variation in training was accomplished by introducing new drills every 4^{th} session to provide variety and a progressive overload approach to training. New drills were introduced prior to all training sessions by way of a handout with a brief explanation as well as a demonstration by the investigator.

All players were encouraged to keep their eyes and heads up focusing on a piece of colored tape that was positioned on the wall in front of them. Participants assigned to the RV training group wore a visual blocking facemask screen to provide an additional challenge and was inserted on their helmet cage as previously illustrated (Figure 3). All training sessions were timed and supervised by the same instructor with additional trainers assisting to monitor the accuracy and effort of drills and encouraged the participants to put forth a maximal effort. Make up sessions were scheduled when participants missed a session to ensure completion of the required number of sessions.

3.6 Dependent and Independent Variables

The dependent variables examined were: puck control (reps in 20 seconds), grip strength (kg), motivational questionnaire, wrist shot speed (mph), shot release (seconds) and shot accuracy (number of targets hit). The independent variable was the order of condition (NV-RV or RV-NV).

3.7 Statistical Procedures

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) software (17.0 for Windows, Chicago, Ill.). Descriptive statistics were calculated for all recorded variables. A mixed model analysis of variance (ANOVA) was used to determine significant differences between in PRE, POST1 and POST2 puck control, shooting performance variables (simple and complex stickhandling scores, shot speed, release and accuracy) and grip/forearm strength as a result of the SPC training and training groups (NV-RV and RV-NV). Pairwise comparisons using the Least Significant Difference adjustment identified where the significant differences were located. An alpha level of $p \leq 0.05$ was established for statistical analyses. A paired samples t-test was used to assess potential SPC skill levels. Furthermore, the averaged results of the motivational questionnaire (interest/enjoyment and effort subscales) were analyzed in comparison to the SPC training results. Effect size values (*Cohen's d*), were evaluated to supplement the differences of each training group. A Pearson's Product Moment Correlation Coefficient (*r*) was used to investigate the strength of the relationship between all variables: SPC, shooting, forearm/grip strength and player descriptives (height and weight).

CHAPTER 4: RESULTS

4.1 Player Information

The player demographic information collected from the player questionnaire is detailed in Table 4 and Table 5. Subjects averaged 13 years of hockey experience, with the majority previously playing varsity or AA level of hockey. The player's used their own composite sticks which were normally used for practices and games. The majority of the team (83%) reported that their participation in off-ice SSP training during the off-season was minimal. More specifically, 39% indicated they never practiced shooting and 44% practiced only 1-2 times over the entire summer. Only 22% of the team had been previously exposed to the simulated shooting training device, the RapidShot™, which was used for the purpose of the study.

Forearm/Grip Strength

The combined score (dominant and non-dominant hands) was used for analysis with scores detailed in Table 6. Results indicated that there was no overall difference in forearm/grip strength performance as a result of the 16 SPC training sessions F (1.29, 32) = 1.04, p = .339, (η_p^2 = .061). There were also no overall significant differences in scores as a result of the order of training groups F (1, 16) = .935, p = .348, (η_p^2 = .060).

4.2 SPC Puck Skills

Overall, both simple and complex SPC skills showed significant improvement over the 16 SPC training sessions, excluding the complex test in NV which was significant only POST1-POST2. No significant differences in SPC performances were found for the sequencing of training groups (NV-RV vs. RV-NV). However, from a practical perspective, performance scores consistently favored the RV-NV training group, meaning that the order of training condition has the potential to be more beneficial.

Simple SPC Puck Skills: *Normal Vision Tests*

There was an overall significant difference in the side to side test performed in the normal vision condition, F (2, 32) = 8.761; p = .001, (η_p^2 = .354), meaning the subjects significantly improved their scores on this side to side tests over the 16 session intervention (Figure 8). Descriptive statistics for simple SPC tests in the normal vision condition are detailed in Table 7. Pairwise comparisons for the side to side tests using the LSD adjustment indicated that the overall significant differences occurred between PRE-POST 2 (MD = 3.98, SE = 1.10; p = .002) and POST 1 -POST 2 (MD = 3.75, SE = .83; p = .000) tests. The main effect of side to side tests also indicated a significant linear trend, F (1,16) = 13.157; p = .002 (η_p^2= .451), meaning that regardless of training condition, the overall test scores progressively improved throughout the SPC testing times. There was no overall statistical difference for the order of training groups, F (1, 16) = 0.603; p = .449 (η_p^2 = .036) suggesting that the order of training did not produce significantly different results (NV-RV vs. RV-NV) on the simple NV test. Despite being non-significant, practically both groups showed similar overall large effects for those who trained RV-NV (d = 1.04) and NV-RV (d = .90). Table 8 further details the specific effect sizes at POST1 and POST2 testing sessions. These results emphasize the large significant improvements seen from POST1 to POST2.

Simple SPC Puck Skills: *Restricted Vision Tests*

There were significant overall differences for the side to side test performed in the restricted vision condition, F (2, 32) = 16.741; p = .000 (η_p^2 = .511), meaning the subjects significantly improved their scores on this side to side tests over the 16 session intervention (Figure 9). Descriptive statistics for simple SPC tests in restricted vision are also detailed in Table 7. Pairwise comparisons for the main effect of side to side tests using the LSD adjustment indicated that the significant differences occurred between PRE- POST 1 (*MD* = 2.98 , *SE* = .92 ; *p* = .005), POST 1 –POST 2 (*MD* = 2.45 , *SE* = .90; *p* = .015) and PRE-POST 2 (*MD* = 5.43 , *SE* = .99; *p* = .000) tests. The main effect of side to side tests also indicated an overall significant linear trend, F (1,16) = 29.908, p = .000 (η_p^2 = .651), meaning that the subjects progressively improved their simple RV test scores over the 16 SPC sessions regardless of training order. There was no overall statistical significant difference found for the order of training groups, F (1, 16) = 3.819; p = .068 (η_p^2 = .193), such that the order the groups trained in (NV-RV vs. RV-NV) did not produce significantly different results after the 16 SPC training sessions. However, a simple main effect at POST 1 testing showed a significant difference between groups due to the different training conditions (*MD* = 3.48, *SE* = 1.63; *p* = .049). Practically, a slight greater overall effect size was found for those who trained NV-RV (*d* = 1.87) over those who trained RV-NV (*d* = 1.35). Table 8 further details the specific effect sizes at POST1 and POST2 testing sessions. From this data, it can be seen that the specific type training (RV) prior to the RV test was beneficial regardless of training order for the simple SPC test.

Complex SPC Puck Skills: Normal Vision Tests

Overall, there were statistically significant differences for the figure 8 (complex SPC) tests in the normal vision condition F (2, 32) = 3.374; p = .047 (η_p^2 = .174). Pairwise comparisons for the main effect of the figure 8 tests in the normal vision condition using the LSD adjustment indicated that the overall significant differences occurred between the POST 1-POST 2 tests (*MD* = 1.39. *SE* = .56; *p* = .024). Descriptive statistics for complex SPC tests in the normal vision condition are detailed in Table 9. No overall statistical significance was found for the order of training groups, *F* (1, 16) = .373, *p* = .550 (η_p^2 = .023), thus subjects in NV-RV did not produce significantly different results from those who trained in RV-NV during the complex SPC test in normal vision (Figure 10). Despite showing no statistical significance for the order of training groups, this figure 8 test in the normal vision condition showed a greater overall practical effect for those who trained RV-NV (*d* = 1.35) over those who trained NV-RV (*d* = 0). The complex test in NV produced the greatest improvement in scores training in NV for the last 8 sessions. Table 10 further details the specific effect sizes of complex SPC in NV at POST1 and POST2 testing sessions.

Complex SPC Puck Skills: Restricted Vision Tests

There were overall statistical significant differences for the figure 8 tests in the restricted vision condition, *F* (2, 32) = 6.683; *p* = .004 (η_p^2 = .295) after the 16 training sessions (Figure 11). Descriptive statistics for complex SPC tests in the restricted vision condition are also detailed in Table 9. Pairwise comparisons for the main effect of the figure 8 tests using the LSD adjustment indicated that the overall significant differences occurred between the PRE-POST 2 tests (*MD* = 1.18, *SE* = .31; *p* = .001). The figure 8 test in the restricted vision condition also indicated a significant linear trend, *F* (1,16) = 14.875; *p* =.001 (η_p^2 = .482) meaning that the subjects achieved an overall improvement in complex RV scores. No statistical significance was found for the order of training groups, *F* (1, 16) = 1.049; *p* = .321 (η_p^2 = .062), suggesting that subjects in NV-RV did not produce significantly different results from those who trained in RV-NV. However, as a result of the different training conditions, a simple effect at POST 1 testing showed significant statistical performance differences (*MD* = 1.03, SE = .48; *p* = .048) between groups. Despite showing no overall statistical significance for the order of training groups, the figure 8 test in restricted vision had greater overall practical significance for those who trained RV-NV (*d* = 1.37) over those who trained NV-RV (*d* = 1.02). Table 10 further details the specific effect sizes for complex SPC in RV at POST1 and POST2 testing sessions. Similar to the simple SPC results in RV, the largest effects were seen after training in the RV condition.

4.3 Wrist Shot Performance Variables

Of the three shooting performance variables examined (speed, release and accuracy), accuracy was the only variable that revealed significant improvements over the 16 SPC training sessions.

Wrist Shot Speed

Overall, shooting speed was not significantly different *F* (2,32) = 1.710; *p* = .197, (partial η^2 = .096), suggesting that there was no difference in wrist shot speed performance after the 16 SPC training sessions (Figure 12). However, there was a significant linear trend for the interaction effect of shooting speed test and visual condition *F* (1,16) = 5.745; *p* = .029 as seen in the progressive improvements of the shooting trials for RV-NV and not the NV-RV group (Table 11). This trend suggests that the order of SPC training may have placed an effect on wrist shot speed over the course of the study as shown by the significant simple main effect between groups at POST 2 (*MD* = 4.80, *SE* = 1.64; *p* =.010) test speed scores with higher speeds for the group that trained RV-NV. The overall results however indicated no overall significant differences for the order of training groups, F (1, 16) = 3.086; p =.098 (η_p^2 = .162) thus, subjects in NV-RV were not significantly different from those who trained in RV-NV. Despite showing no statistical significance between groups, the wrist shot speed test showed a greater overall practical effect for those who trained RV-NV (d = .53) over those who trained NV-RV (d = .22). Table 12 further details the specific effect sizes of shooting speed at POST1 and POST2 testing sessions.

Wrist Shot Release Time

There were no overall statistically significant differences of shooting release PRE-POST2, F (2, 32) = .121; p =.310 (partial η^2 = .071), suggesting that the 16 SPC training sessions had no effect on wrist shot release (Figure 13). Complete descriptive statistics for shooting release are detailed in Table 13. No significant differences were found for the order of training groups, F (1, 16) = .124; p =.729 (partial η^2 = .008) thus, subjects in group training NV-RV did not produce significantly different shooting release times from those who trained in RV-NV. Table 12 also details the specific effect sizes of shooting release at POST1 and POST2 testing sessions.

Wrist Shot Accuracy

There was a significant difference, F (2, 32) = 11.409; p = .000 (partial η^2 = .416), in overall shooting accuracy over the 16 SPC training sessions (Figure 14). Table 14 details complete descriptive statistics for wrist shot accuracy. Pairwise comparisons for shooting accuracy using the LSD adjustment found overall significant differences between PRE-POST2 (p = .000) and POST1 – POST2 (p = .004) accuracy tests. A significant linear trend for the main effect was also found F (1,16) = 27.898, p = .000

(partial η^2 = .636),suggesting a progressive improvement in overall shooting accuracy scores regardless of training order. There was also a significant interaction effect for the main effect of shooting accuracy test by visual condition, F (2, 32) = 7.279, p = .002 (partial η^2 = .31) such that the two training groups were performing differently at the testing trials. This interaction effect also showed a significant linear trend, F (1,16) = 13.597, p = .002 (partial η^2 = .459).

No overall significant differences were found for the order of the training groups for the accuracy tests, F (1, 16) = 2.837; p = .112 (partial η^2 = .151) suggesting that subjects in the NV-RV group did not significantly improve from those who trained in RV-NV group after the 16 SPC sessions. However there were statistically significant differences of the simple main effects found between the two groups at POST1 (*MD* = 2.30, *SE* = .81; p = .011) and POST2 testing (*MD* = 2.18, *SE* = .99; p = .043) with accuracy performances of subjects training RV-NV being consistently higher. Practically, the group training RV-NV (d = 1.45) had a greater overall effect then those who trained NV-RV (d = .34), both with large effects after the RV training condition regardless of training order. Table 12 also details the specific effect sizes of shooting accuracy at POST1 and POST2 testing sessions.

4.4 Correlations of Grip Strength, Height, Weight, SPC and Rapidshot™ Variables

Height was significantly correlated with POST1 (r = .481 , n = 18, p = .043) and POST 2 (r = .562 , n = 18, p = .015) combined grip strength, weight was significantly correlated with PRE (r = .698 , n = 18, p = .001), POST1 (r = .703, n = 18, p = .001) and POST2 (r = .786, n = 18, p = .000) combined grip strength and PRE (r = .523 , n = 18, p

= .026) and POST2 (r = .549, n = 18, p = .018) speed, suggesting that bigger and heavier subjects had stronger upper body strength and produced faster shots.

POST2 figure 8 scores in NV were significantly correlated with PRE release (r = -.708, n = 18, p = .001), POST1 release (r = -.586, n = 18, p = .011) and POST2 release (r = -.572, n = 18, p = .013) time scores, such that the higher figure 8 scores were correlated to the faster release times on the Rapidshot™ shooting test.

4.5 Skill Level

The subject's PRE SPC scores for the simple test in NV compared to the same task while performing a cognitive task (also in NV) resulted in no significant differences t (17) = 1.76; p = .096. However, there were significant differences when comparing the complex test in NV and while performing the cognitive task (also in NV), t (17) = 4.70; p = .000. This suggests that the complexity of the figure 8 task provided a greater challenge to the player's skill level than the simple test. This helped to identify how advanced the subjects were for the SPC skills.

4.6 Motivational Questionnaire

The motivational questionnaire examined the interest/enjoyment and effort subscales from the *Intrinsic Motivation Inventory*. Consistently, the group that trained in RV reported higher interest/enjoyment and put forth more effort, excluding the group who trained NV last who reported slightly more effort than those who trained in RV last. Overall both the interest/enjoyment and effort increased from POST1 (Table 15) to POST2 testing (Table 16).

CHAPTER 5: DISCUSSION

The primary purpose of this study was to investigate the effect of a 16 session stickhandling and puck control (SPC) training intervention on SPC drills and shooting performance variables in female collegiate hockey players. A secondary purpose was to examine the effects of integrating restricted vision into the training regime as a potential method of overload for SPC skill development. Female athletes were targeted for the purpose of the study as it has been suggested that these players possess a weaker SPC skill set in comparison their male counterpart of the same age and level (Leiter, 2001). Results revealed significant improvements in SPC skills with 16 sessions of SPC training. Both simple and complex SPC skills, which were deemed to represent a player's overall ability to manipulate the puck, improved with SPC training. The SPC skills tested were reflective of the skills being trained. The shooting performance variables did not reveal consistent improvements with SPC training. Although it is assumed that SPC skills are a pre requisite to shooting success, the variables measured (speed, release and accuracy) were not specifically trained in the study and therefore made it difficult to produce a complete transfer of skill after the training. Finally, the order of training conditions (NV-RV and NV-RV) did not produce statistically different scores from each other; meaning that the order of the training stimulus did not produce a greater effect than the training volume itself. Although from a performance perspective, the group training RV-NV consistently showed greater performances, as seen through the greater overall effect sizes.

SPC Training Methodology Development

Stickhandling and puck control (SPC) have been identified as important skills for hockey players (Merrifield and Walford; 1969; Renger, 1994; Montgomery, Nobes & Turcotte, 2004); however it is often assumed that these skills are acquired through mere repetition and game play as opposed to more formal training programs. There has been unequivocal attention to the training of this skill in comparison to training the physiological and biomechanical aspects of shooting. Developed SPC skills allow for enhanced puck possession abilities that create the potential to increase scoring opportunities during game play.

The current study isolated the skills of stickhandling and puck control. The off-ice SPC training drills were used to develop the player’s ability to manipulate the puck using an artificial ice surface. The 16 SPC sessions were ten minutes in duration with intermittent rest to ensure adequate time for training the skill as well as ensuring the skill could be properly introduced, developed and potentially overloaded to produce adaptation without fatiguing the skill to the point of failure. The SPC training utilized a progressive drill set developed to elicit an improvement in of the SPC techniques. Multiple sets of drills, 20-30 seconds in duration, were used. The overall training volume for the current study was 160 minutes of technical training.

Physiological loading is typically defined as an increase in intensity or stress placed on the physiological system. Adaptation is a more or less persistent change in structure and/or function following training that apparently enables the body to respond more easily to any subsequent bouts of exercise. In a physiological system, the process of adaptation typically occurs as a result of fatiguing the given system to the point of failure, followed by a period of rest. When training a mechanical or technical skill, the process of adaptation including how to effectively overload the skill in order to elicit a training response, is not as well defined. However, it is proposed that fatigue may not be an effective stimulus for technical training for the following reasons. As the subject fatigues, technique typically breaks down. As a result, the mechanics change and continued practice would therefore, reinforce repetition of compromised mechanics as opposed to stimulate a positive change in mechanical efficiency or technique.

The current study utilized two methods of overload to challenge mechanical adaptation during the SPC skill training: a) complexity of drills and b) restricted vision. The complexity of drills progressed from simple to complex sequences which involved tasks using a larger puck-blade contact area for stickhandling while in the same plane, to more complicated and multidirectional movements that used smaller parts of the blade. All drills were performed with and without vision. The restricted vision condition was added to further challenge the subject's cognitive and kinesthetic ability beyond the skill being performed with normal vision. A facemask screen inserted onto helmet's facemask blocked vision and also encouraged players to keep their heads up when stickhandling as they could see neither the puck nor their stick. Participants relied on their kinesthetic and spatial awareness in determining the optimal locations on the blade to manipulate the puck through the drill patterns. The heads up approach to training also has significant safety implications. In the women's game, a heads up approach is not typically enforced because of the lack of intentional body contact in the game environment. However, a heads up approach trains the player to become more kinesthetically aware and decreases the chance of collision-related injuries.

SPC Training Outcomes and the Challenge Point Framework

The Challenge Point framework (Guadagnoli and Lee, 2004) is used to assess performances from the related information available during the specific motor tasks. Although the framework is cognitive in nature, it could be applied to the development of mechanical skills. The Challenge Point Framework describes the relationship between three components: task difficulty, skill level and practice condition. From these three components, functional task difficulty (nominal task difficulty, skill level and practice conditions) is determined and essentially establishes the amount of potential information available for learning (Guadagnoli and Lee, 2004). Through functional task difficulty, an optimal challenge point can be determined, which would represent the "degree of functional task difficulty an individual of a specific skill level would need in order to optimize learning" (p. 216).

In the current study, skill complexity or nominal task difficulty was defined as simple or complex, which ranged from low to high levels for each of the SPC tasks respectively. The simple, side to side task was very basic and therefore could be completed very easily once the subjects were familiar with the drill. The complex, figure 8 task was more difficult as it required more dexterity and control to maneuver the puck continuously. The difference in the number of repetitions completed for the complex, figure 8 task (low repetitions) compared to the number of repetitions completed for the simple, side to side task (high repetitions) confirms the increased nominal task difficulty for the figure 8 task.

The second component of the CPF was skill level. For the purpose of the study, the skill level of the subjects was determined by a cognitive SPC test which compared both simple and complex stickhandling abilities performed during normal vision and subsequently performed with the additional cognitive task of counting backwards by 3's. A comparison of these results revealed that the additional cognitive component had no effect on the simple tasks however further challenged the complex task, meaning that the complex skills were not as automated and required conscious thought for proper execution. The CPF also states that as the nominal task difficulty increases, the performance rates will decline faster for the less skilled individuals (Guadagnoli and Lee, 2004). The range of individual subjects abilities in the current study was reflected in a range of SPC scores declining from ~24 to ~6 repetitions for the simple and complex tasks in NV respectively.

The third component was practice condition. Subjects were required to complete training in both normal and restricted vision training conditions. The RV condition was more challenging as it reduced the amount of feedback the player received during training and therefore, provided an overloaded stimulus.

In summary, the compound of effect of the three components outlined above determined the functional task difficulty of the SPC tests. The tests could therefore be ranked in order of easiest to hardest as follows: simple NV (lowest functional task difficulty), simple RV, complex NV followed by the hardest task of complex SPC in RV (highest functional task difficulty). Functional task difficulty or the composite measure of the contributing components can therefore be used to interpret the players' performances on these tests.

When examining the participant's current skill level and practice conditions coupled to the low task difficulty of the simple SPC skills, it was evident that this task did not provide adequate information for maximal learning to occur throughout the study.

The lower nominal and functional task difficulties of the simple SPC tasks suggested that moving from training conditions did not increase the difficulty for the subjects to a far enough extent as seen through the similar overall effect sizes of both training groups (NV-RV and RV-NV) for both simple tests even after training in another condition. Both groups improved their simple SPC skills for the NV and RV tests significantly over the course of the study, suggesting that exposure to the skill training was beneficial, as both groups (when training in different conditions) showed a similar pattern of improvement. Despite PRE-POST2 scores producing the largest improvement for both tests, overall the simple NV test had its largest improvement POST1-POST2 whereas the simple RV test improvements were largest PRE-POST1. Reasons contributing to the increase differences may be due to the participants acquiring improved mechanics such as cradling the puck to prevent the puck from bouncing off the stick during the simple task at higher speeds in later stages of the study in NV. However, during the RV test, subjects were initially forced to complete the drill at slightly slower speeds due to the unfamiliarity of not being able to visually monitor the movement of the puck during the drills. This however may have resulted in the slower movements being more accurate which may have contributed to the continual improvement for both groups on the RV test and with practice, were able to perform the skill faster and more continuously. The small improvements in both groups after the first 8 training sessions on the NV test (regardless of training condition) were smaller in comparison to the improvements initially produced on the RV test. The participant's greater effort during the task could have potentially contributed to this difference. For both simple tests, after training in the more difficult RV condition, larger effects were seen in comparison to the results after training in NV.

The complex SPC drill was more difficult for these participants and their abilities with respect to the practice conditions and therefore provided an optimal challenge. The complex SPC test in RV was the most challenging of the tasks to complete, as this certain task increased the amount of uncertainty and available information, providing the potential for learning and ultimately greater skill performance. In the RV condition, too much information may have been available and was counterproductive for the subjects as seen in the reduced number of repetitions they were able to complete, as one repetition required a considerable amount of skill and dexterity in order to maneuver the puck for proper completion. The low average repetitions completed ranged from 6.20 to 8.62 repetitions during the NV test and .38 to 1.60 repetitions during the RV test. This could be predicted, as previously knowing the approximate SPC skill level of the participants, adding additional challenge to the complex skill would make the already hard skill even more difficult to succeed. Therefore the figure 8 task in NV could be proposed as the optimal challenge point with respect to the subjects SPC skill level. This overload of information for the player's given skill was seen in the RV test and was very prominent when the subjects took the complex RV test after training in NV and had no improvements in their scores. The RV test showed the greatest improvement PRE-POST2, whereas the greatest improvements for the NV test were POST1-POST2. The largest improvements for the NV test suggested the subjects' overall ability to manipulate the puck improved as the training volume (total number of sessions completed) increased. The complex RV test scores were higher immediately following the RV training, as seen in the consistently greater responses after RV training due to the specific training received. The NV-RV training group had an overall effect of zero on the NV test, potentially suggesting that the complex skill was not adequately learned before overloading and challenging the subjects by removing the players' vision. Additionally, as the training group RV-NV had greater overall effects for the complex SPC tests, the order in which the challenge was presented potentially had a positive influence on performance.

Results suggested that the RV training condition provided more challenge and therefore may have been more beneficial for learning. This result was supported by the motivational data collected from the players throughout the study which also suggested that the order of the training condition had an effect on interest/enjoyment and effort during training. The group that trained RV prior to NV consistently put forth more effort and this may have increased the interest/enjoyment of the task more in comparison to the group that trained NV prior to RV. This suggests that if a greater challenge is presented initially, subjects were more engaged in training and resulted in greater improvement. Although challenging, restricted vision training first may also have been too challenging for some, and was potentially reflective in the lower interest/enjoy scores than those training NV first because of the constant errors made. In contrast, the NV-RV training group may have found the tasks not interesting enough in NV such that the players self reported that they did not try very hard in comparison to the scores of the group training RV first (Table 15). Therefore when the NV group switched to RV training, it was more difficult and participants were frustrated easily because of the consistent mistakes and therefore reduced effort. The group switching to NV could then experience success for the tasks and put forth more effort in the task. The simple test in RV was the only test that showed greater overall effects/improvements for the NV-RV group and that could have been contributed to the lower initial PRE scores on that test. In addition, for the side to side test, subjects may have reached a ceiling effect, such that there was not much room for improvement within the 20 seconds when already possessing advanced skills for the specific task. The complex task however may have produced a floor effect, such that there was more room to improve with regards to the participant's abilities.

Anticipation of Transfer

The three performance variables (shooting speed, release time and accuracy) were assessed pre and post training with shooting accuracy being the only performance that improved with SPC training. It is proposed that although the SPC training regime provided a training stimulus for technical improvement, the training type did not provide a muscular overload to potentially see any improvements in speed and release time.

Significant improvements in wrist shot accuracy was not surprising as both wrist shot accuracy and stickhandling drills are precision tasks. Michaud-Paquette, Pearsall & Turcotte (2009) found that the strongest predictors of wrist shot accuracy were the puck's position on the blade, puck linear release velocity, changes in the blade's orientation and shaft bend recoil. The puck/blade positioning and orientation are components trained during the SPC drills, such that the training potentially increased the player's ability to maneuver and cradle the puck, allowing for proper positioning not only when stickhandling, but in the preparatory and action phases of shooting a wrist shot. Thus, proper recognition of the puck/blade interactions that could have occurred in SPC training may have heighted the players ability to identify similar positions on the blade, especially when having to keep their heads up to identify the quick corner target light. Practically, the group RV-NV performed better and this is strengthened by the large differences between the groups at both the POST1 and POST 2 tests, suggesting that this training order placed a greater effect on accuracy.

As previously mentioned and should it be noted that the targets in the current study were completely random, therefore an unequal number of targets were selected for the top/bottom and ipsilateral and contralateral sides. Michaud-Paquette, Pearsall & Turcotte (2009), found that the accuracy scores of top targets were 20% lower than the bottom corners, however this result was not surprising because hitting the top corners requires a more complex trajectory as the puck cannot just remain on the ground to hit the target, like the bottom corners. In the current study, shooting at the bottom targets posed a similar scenario. Based upon these results, the subjects who had a series in which the bottom corners were selected more frequently would technically have an accuracy advantage over those who had more top corners; however the subjects still had to hit the target. Consequently, the number of bottom and top corners selected was not recorded during the testing. Overall, the subjects in the current study increased their average shooting percentages by approximately 12% (27.06%-38.56%). The 12% accuracy improvement may be the result of the player's having improved puck control for proper puck/blade manipulation prior to shooting as previously suggested. Lastly, Emmert (1984) also identified that the top arm during the slap shot (stabilizer arm) helps direct where the puck will go, and thus during the SPC training, the muscle discomfort felt by the subjects in their top arm shoulder potentially may have contributed to the subjects success in directing the puck towards the net. This claim however is well beyond the scope of this study. The improvement in wrist shot accuracy was small, however due to the increased ability of the players to manipulate the puck may have potentially lead to the transference of skill allowing the players to keep their heads up to identify the proper targets. The heads up mentality was strengthened not only through the training, but also in testing due to the quick random corner selection. However, due to the differing skill levels for wrist shot mechanics, it is difficult to make concrete conclusions for the SPC skills transferring to the shooting skill.

Shooting Speed and Release Analysis: Despite the lack of overall significance in shooting speed, a significant linear trend of the interaction of speed tests and visual training groups was indicative of progressive difference over the course of the study. Within these improvements, although non-significant, subjects training RV-NV produced an overall larger effect and most noticeably, the biggest difference occurred after NV training POST1-POST2. NV training for the last 8 sessions prior to testing had the largest effects on speed. In this SPC condition, subjects were able to maintain better control of the puck while stickhandling, sustaining constant SPC training that was not as frequently disrupted by error, such as training in the RV condition. The current study did suggest that the players with stronger grip/forearm strength are capable of shooting faster, and no differences seen in strength PRE and POST2 would also support this, however because this was not a strength study, no overload was provided for its improvement.

The significant negative correlations found between PRE, POST1 and POST2 shooting release times and POST2 SPC figure 8’s in normal vision are suggestive that those who had greater puck manipulation skills at the end of the study were able to release the puck faster. This finding can be in accordance with the findings of Michaud-Paquette et al., (2009), such that the higher caliber players had greater rates of change in blade orientations when shooting and how puck-blade position was found to be important factor in the accuracy of the shot. The 2009 study suggested that during the wrist shot, the puck is guided and cradled forward on the blade such that the puck-blade position was controlled throughout the movement as a result of wrist and forearm supination/pronation. Thereby, the increase in dexterity that may be a result of previous or developed SPC skill could possibly aid a players' ability to properly control the puck on the blade during the wrist shot allowing a faster release.

Limitations

Due to the off- ice nature of the study, the participants performed testing and training sessions without skates. This allowed for a convenient off- ice training method however the subjects were trained from static positions, whereas the game of hockey is dynamic. The sample size was small, reducing the overall power and resulted in the use of effect sizes (practical significance) for between subject analyses. Lastly, the commercial device showed some mechanical inconsistencies during some testing sessions; however re-trials were completed for the subject's proper assessment. The computerized scoring of shooting device also only recorded data for shots that hit any of the four targets. Any shot that missed, the corresponding shot data (speed and release) was discarded and the missed scores were not included in the average of the 16 shot test. Therefore the data for the speed and release analysis were dependent on the number of targets hit.

Practical Implications

This study has provided some insight into an effective stickhandling and puck control training regime that could be conducted in a convenient off- ice setting. A minimum of 16 SPC training sessions, 2 to 3 times a week for 10 minutes can translate into significant improvements and can be easily integrated into an off- ice hockey program. Additionally, this study provided support for an alternative overload strategy to teach and train technical skills, however knowing the participant’s skill level will be helpful to properly incorporate this challenge. Providing this alternative challenge potentially promotes further skill development that may allow for greater control for both SPC and shooting accuracy. This also potentially provides increased confidence to look at the targets, which ultimately allows players to focus on other aspects of the game, such as open ice, target selection and opponent identification.

Conclusion

Training SPC drills had a positive effect on both simple and complex SPC skills. The enhanced dexterity allowed players to manipulate the puck more efficiently and also identify where the puck needed to be located on the blade for proper and faster drill completions. Improvements in SPC skills appeared to be a result of training volume of specific skills as opposed to the order in which the training stimulus was provided. This meant that the amount of exposure to the training was a greater stimulus then the specific order of training conditions received. The subjects were challenged by restricting the player’s vision (RV condition) and despite no significant difference between training groups; there were consistent performance improvements for those who trained RV-NV. Lastly, SPC training has the potential to be easily incorporated into off-ice training regimes for hockey players to further develop these skills.

Although it was recognized that some participants improved shooting performance, consequently, training SPC skills did not transfer to an improvement in all shooting performance scores. The increase in shooting accuracy could be attributed to the greater improvements in the player’s ability to maneuver the puck with the blade, which may have given the players confidence to keep eyes on the target as opposed to the puck which allowed for proper target identification. Therefore SPC skills do not ensure the success of the wrist shot as they are two different skill sets.

Recommendations for Further Study

Future studies examining SPC skills are recommended to assess different age, gender and skill levels such as players early in the developmental stages where motor patterns for stickhandling have not been developed. Determining an age/development stage where SPC training would provide maximal benefits to the player would be an asset to all coaches. Additionally, future studies should include SPC sessions in only RV and NV to determine the effect of just the single condition on these skills.

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TABLES

Table 1

Ontario University Athletics (OUA) Women's Hockey Statistics: 2007-2008 Regular Season Goals Scored by Team (GP = 27)

Rank	Team	Goals scored	Final regular season standings
T1	Laurier	97	1
T1	Toronto	97	2
3	Guelph	77	3
4	York	72	5
5	Queens	69	4
6	Western	62	7
T7	Windsor	51	6
T7	Brock	51	8
9	UOIT	43	10
10	Waterloo	39	9

Mean goals scored: 65.80

Note. GP = number of regular season games played; UOIT = University of Ontario Institute of Technology. From, Canadian Interuniversity Sport [electronic source], http://www.universitysport.ca

Table 2

Ontario University Athletics (OUA) Men's Hockey Statistics: 2007-2008 Regular Season Goals Scored by Team (GP = 28)

Team	Goals scored	Team	Goals scored
West		East	
UQTR	112	Brock	94
McGill	102	York	103
Ottawa	83	Guelph	82
Carleton	88	UOIT	60
Queen’s	77	Lakehead	129
Toronto	86	Western	108
RMC	71	Waterloo	119
Ryerson	95	Laurier	120
		Windsor	72
Mean goals scored: 94.17			

Note. GP = number of regular season games played; UQTR = Université du Québec à Trois – Rivières; RMC = Royal Military College; UOIT = University of Ontario Institute of Technology. From, Canadian Interuniversity Sport [electronic source], http://www.universitysport.ca

Table 3

Literature Summary of Shooting Targets and Distances

Author (Year)	Target Type	Distance (Puck to Target)
Alexander et al. (1963)	ballistic Pendulum	various distances
	2ft square (chalk covered)	
	4 x 6 goal	
	5pts for hitting centre of target	
Alexander et al. (1964) & 18ft)	ballistic Pendulum	2 ice markings (10ft
	similar to Alexander et al., 1963	must shoot before second line
Cotton (1966)	hockey net	28 feet
	accuracy not examined	
Merrifield & Walford	20inch square hung 1foot above	20 feet from goal
(1969)	ice in centre of goal.	
Nazar (1971)	4ft x 6ft target	20 feet from goal
	4 concentric circles (bullseye)	
	Goal divided into quadrants	

Author (Year)	Target Type	Distance
Doré & Roy (1973)	shot at target but not specified	not specified
Roy & Doré (1976)	Shot at target but not specified	Not specified
Sim & Chao (1978)	target 4ft x 8ft with smaller target in middle	approximately 30-40ft
Moyls (1978)	shoot at middle of net as hard as possible	standing at blueline
Rothsching (1997)	target 60cm x 60cm	not specified
Leiter (2001)	-target 30cm in diameter suspended from crossbar hanging in the center of the net (analysis) -Accuracy test 4 plexiglass targets 30cm diameter placed in the corners of the net	6m from goal
Wu (2002)	target 0.60m x 0.60m	3 meters to target

Author (Year)	Target Type	Distance
Polano (2003)	outlined against the end boards 0.95m x 0.84width	Middle hash mark
Fergenbaum & Marino (2004)	regulation net	faceoff circle closest line (net in front)
Woo (2004) target	target area 130cm x 113cm	3.34m away from
Lomond (2005) target	target 0.85m wide x 1.13m high Puck covered in chalk dust	~4.4m away from
Villaseñor et al. (2006) target	target 0.60m x 0.60m	3.3m away from
Michaud-Paquette et al. (2009)	Shooter Tutor- 4 corners 0.35m x 0.40m	4m away from target
Gilenstam et al. (2009)	regulation net	7m from target

Table 4

Female Collegiate Ice Hockey Player Descriptives (n = 18)

Measure	Mean	SD
Age (years)	19.67	± 1.72
Height (cm)	167.28	± 5.58
Weight(kg)	71.21	± 10.98
Hockey Experience (years)	12.50	± 3.73
Eligibility Year[a]	2.17	± 1.43
Primary Position Played		
Forward	12	
Defense	6	
Shooting Direction		
Left	10	
Right	8	

Note. SD = standard deviation , [a] A student-athlete has a total of 5 years of eligibility

Table 5

Female Collegiate Ice Hockey Player Questionnaire (n = 18)

Measure	Frequency	Percent
Previous hockey level		
Varsity	8	44.4
Intermediate AA	4	22.2
Midget AA	4	22.2
Other	2	11.1
Shooting practice over the summer		
Never	7	38.9
1-2 times	8	44.4
3-5 times	2	11.1
6 + times	1	5.6
Previous experience using the Rapidshot™		
Yes	4	22.2
No	14	77.8

Table 6

Mean and Standard Deviation Scores for Forearm/Grip Strength (n = 18)

Test	Combined Hands (L & R)
Combined (n =18)	
PRE- test	75.66 ± 10.70
POST1- test	74.28 ± 10.92
POST2- test	75.89 ± 11.49
Normal Vision - Restricted Vision (n =10)	
PRE- test	72.75 ± 7.58
POST1- test	72.96 ± 11.09
POST2- test	73.65 ± 10.98
Restricted Vision - Normal Vision (n =8)	
PRE- test	79.30 ± 13.30
POST1- test	75.94 ± 11.22
POST2- test	78.69 ± 12.21

Table 7

Mean and Standard Deviation Scores for Side to Side (Simple) Stickhandling Testing

Test	SS Normal	SS Cognitive	SS Restricted
Combined Conditions (n =18)			
PRE- test	22.83 ± 4.76	20.33 ± 2.67	17.50 ± 4.13
POST1- test	23.00 ± 3.34	19.67 ± 2.54	20.44 ± 3.77
POST2- test	26.78 ± 3.10	22.72 ± 1.93	23.06 ± 2.58
Normal Vision - Restricted Vision (n =10)			
PRE- test	22.60 ± 4.88	20.10 ± 2.56	16.20 ± 4.34
POST1- test	22.30 ± 3.50	18.90 ± 2.60	18.90 ± 4.10
POST2- test	26.30 ± 3.16	22.30 ± 2.31	22.80 ± 2.49
Restricted Vision - Normal Vision (n =8)			
PRE- test	23.12 ± 4.91	20.62 ± 2.93	19.12 ± 3.44
POST1- test	23.88 ± 3.14	20.62 ± 2.26	22.38 ± 2.33
POST2- test	27.38 ± 3.11	23.25 ± 1.28	23.38 ± 2.83

Note. SS = Side to side stickhandling task.

Table 8

Effect Size (Cohen's d) Summary for Simple SPC Tests by Training Group

Simple SPC	PRE-POST1	POST1-POST2	PRE-POST2
NV Test			
RV-NV	0.18	1.12	1.04
NV-RV	-0.07	1.20	0.90
RV Test			
RV-NV	1.11	0.39	1.35
NV-RV	0.64	1.15	1.87

Table 9

Mean and Standard Deviation Scores for Figure Eight (Complex) Stickhandling Testing

Test	Fig Normal	Fig Cognitive	Fig Restricted
Combined Conditions (n =18)			
PRE- test	6.72 ± 2.02	4.61 ± 1.72	0.44 ± 0.78
POST1- test	6.44 ± 2.06	5.67 ± 2.14	1.06 ± 1.11
POST2- test	7.78 ± 1.92	5.66 ± 1.75	1.61 ± 1.14
Normal Vision - Restricted Vision (n =10)			
PRE- test	7.10 ± 2.33	4.40 ± 2.22	0.50 ± 0.85
POST1- test	6.20 ± 2.44	5.20 ± 2.39	0.60 ± 0.70
POST2- test	7.10 ± 1.73	4.90 ± 1.29	1.60 ± 1.26
Restricted Vision - Normal Vision (n =8)			
PRE- test	6.25 ± 1.58	4.87 ± 0.84	0.38 ± 0.74
POST1- test	6.75 ± 1.58	6.25±1.75	1.62 ± 1.30
POST2- test	8.63 ± 1.92	6.63 ± 1.85	1.63 ± 1.06

Note. Fig = Figure eight stickhandling task

Table 10

Effect Size (Cohen's d) Summary for Complex SPC Tests by Training Group

Simple SPC	PRE-POST1	POST1-POST2	PRE-POST2
NV Test			
RV-NV	0.32	1.07	1.35
NV-RV	-0.38	0.43	0
RV Test			
RV-NV	1.17	0.01	1.37
NV-RV	0.13	0.98	1.02

Table 11

Mean and Standard Deviation Scores for Shooting Speed

Test	Average Speed (mph)	Peak Speed (mph)
Combined Conditions (n =18)		
PRE- test	37.74 ± 4.73	39.60 ± 3.15
POST1- test	37.46 ± 2.92	39.71 ± 3.71
POST2- test	38.71 ± 4.15	40.21 ± 4.14
Normal Vision - Restricted Vision (n =10)		
PRE- test	37.18 ± 2.58	38.80 ± 3.00
POST1- test	36.56 ± 2.98	38.15 ± 3.27
POST2- test	36.58 ± 2.88	38.17 ± 3.11
Restricted Vision - Normal Vision (n =8)		
PRE- test	38.44 ± 6.69	40.60 ± 3.24
POST1- test	38.60 ± 2.56	41.66 ± 3.45
POST2- test	41.37 ± 4.07	42.75 ± 3.98

Table 12

Effect Size (Cohen's d) Summary for Wrist Shot Tests by Training Group

Shooting Variable	PRE-POST1	POST1-POST2	PRE-POST2
Speed			
RV-NV	0.03	0.81	0.53
NV-RV	-0.22	0.01	0.22
Release			
RV-NV	-0.38	-0.08	-0.45
NV-RV	0.01	-0.10	-0.09
Accuracy			
RV-NV	1.00	0.63	1.45
NV-RV	-0.53	0.92	0.34

Table 13

Mean and Standard Deviation Scores for Shooting Release

Test	Average Release Time	Peak Release Time
Combined Conditions (n =18)		
PRE- test	0.798 ± 0.170	0.738 ± 0.176
POST1- test	0.773 ± 0.167	0.723 ± 0.176
POST2- test	0.760 ± 0.124	0.700 ± 0.124
Normal Vision - Restricted Vision (n =10)		
PRE- test	0.792 ± 0.178	0.742 ± 0.163
POST1- test	0.793 ± 0.188	0.754 ± 0.199
POST2- test	0.778 ± 0.115	0.710 ± 0.120
Restricted Vision - Normal Vision (n =8)		
PRE- test	0.807 ± 0.169	0.733 ± 0.203
POST1- test	0.748 ± 0.144	0.685 ± 0.147
POST2- test	0.737 ± 0.139	0.689 ± 0.137

Table 14

Mean and Standard Deviation Scores for Shooting Accuracy

Test	Number of Targets hit /16	Percentage
Combined Conditions (n =18)		
PRE- test	4.33 ± 1.94	27.08 ± 12.13
POST1- test	4.72 ± 2.02	29.51 ± 12.65
POST2- test	6.17 ± 2.31	38.54 ± 14.42
Normal Vision - Restricted Vision (n =10)		
PRE- test	4.60 ± 1.83	28.75 ± 11.49
POST1- test	3.70 ± 1.57	23.13 ± 9.79
POST2- test	5.20 ± 1.68	32.50 ± 10.54
Restricted Vision - Normal Vision (n =8)		
PRE- test	4.00 ± 2.14	25.00 ± 13.36
POST1- test	6.00 ± 1.85	37.50 ± 11.57
POST2- test	7.38 ± 2.50	46.09 ± 15.65

Table 15

Mean and Standard Deviation Scores of Motivational Questionnaire POST1 Testing

Question	NV-RV	RV-NV
Interest/Enjoyment Subscale		
I enjoyed doing this activity very much	3.70 ± 1.16	3.75 ± 1.39
This activity was fun to do	3.60 ± 1.17	3.50 ± 0.93
I thought this was a boring activity (R)	4.60 ± 1.17	4.25 ± 1.04
This activity did not hold my attention at all (R)	4.80 ± 0.79	4.75 ± 1.17
I would describe this activity as very interesting	3.80 ± 0.92	3.50 ± 1.07
I thought this activity was quite enjoyable	3.50 ± 0.85	3.62 ± 1.19
While I was doing this activity, I was thinking about how much I enjoyed it	2.80 ± 1.14	2.62 ± 1.19
Average	3.83 ± 1.03	3.71 ± 1.14
RV-NV and NV-RV combined	3.78 ± 1.06	
Effort Subscale		
I put a lot of effort into this	4.50 ± 0.85	5.12 ± 0.84
I didn’t try very hard to do well at this activity (R)	5.00 ± 1.25	5.50 ± 0.93
I tried very hard on this activity	3.90 ± 1.10	5.00 ± 0.76
It was important to do well at this task	4.00 ± 0.94	5.00 ± 1.20
I didn’t put much energy into this (R)	4.90 ± 1.10	5.12 ± 1.89
Average	4.46 ± 1.05	5.15 ± 1.12
RV-NV and NV-RV Combined	4.77 ±1.14	

Table 16

Mean and Standard Deviation Scores of Motivational Questionnaire POST2 Testing

Question	NV-RV	RV-NV
Interest/Enjoyment Subscale		
I enjoyed doing this activity very much	3.90 ± 1.29	4.12 ± 1.13
This activity was fun to do	4.10 ± 1.60	4.00 ± 1.07
I thought this was a boring activity (R)	5.50 ± 0.71	4.62 ± 1.19
This activity did not hold my attention at all (R)	4.80 ± 0.92	5.12 ± 0.84
I would describe this activity as very interesting	3.90 ± 1.20	4.00 ± 1.20
I thought this activity was quite enjoyable	4.20 ± 1.40	4.00 ± 1.20
While I was doing this activity, I was thinking about how much I enjoyed it	3.00 ± 1.25	3.25 ± 1.04
Average	4.20 ± 1.20	4.16 ± 1.10
RV-NV and NV-RV combined	4.18 ± 1.15	
Effort Subscale		
I put a lot of effort into this	5.50 ± 0.71	5.50 ± 0.76
I didn’t try very hard to do well at this activity (R)	5.40 ± 1.27	5.88 ± 0.64
I tried very hard on this activity	4.70 ± 1.25	5.25 ± 0.89
It was important to do well at this task	4.60 ± 1.08	5.50 ± 1.51
I didn’t put much energy into this (R)	5.60 ± 0.97	5.88 ± 0.35
Average	5.16 ± 1.06	5.60 ± 0.83
RV-NV and NV-RV Combined	5.38 ± 0.95	

FIGURES

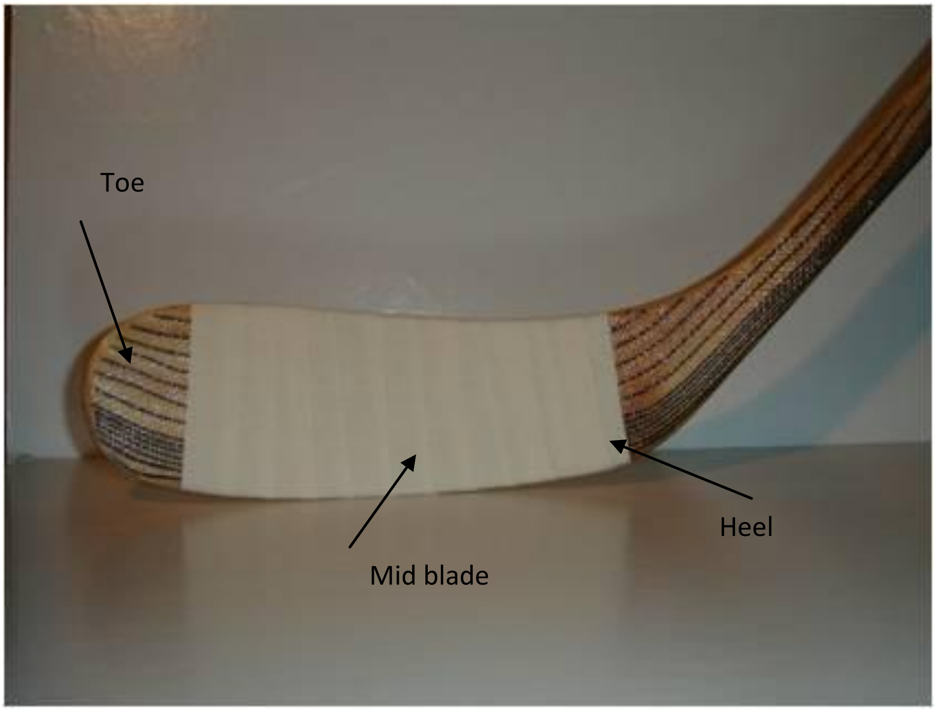


Figure 1. Toe, heel and middle locations of the hockey stick blade.

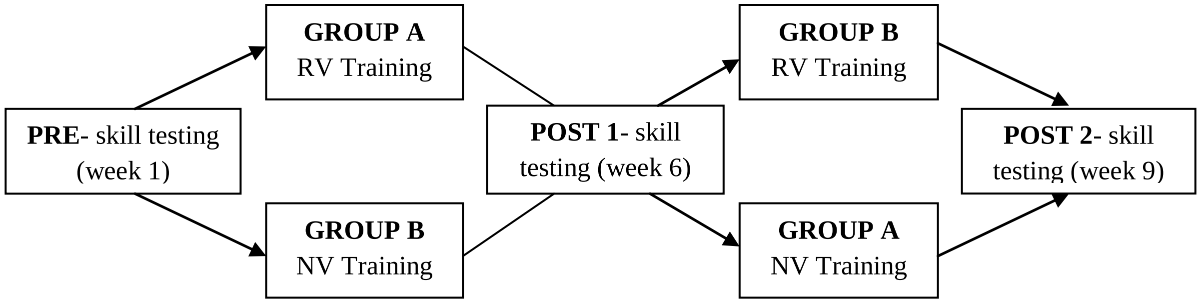


Figure 2. Study design.

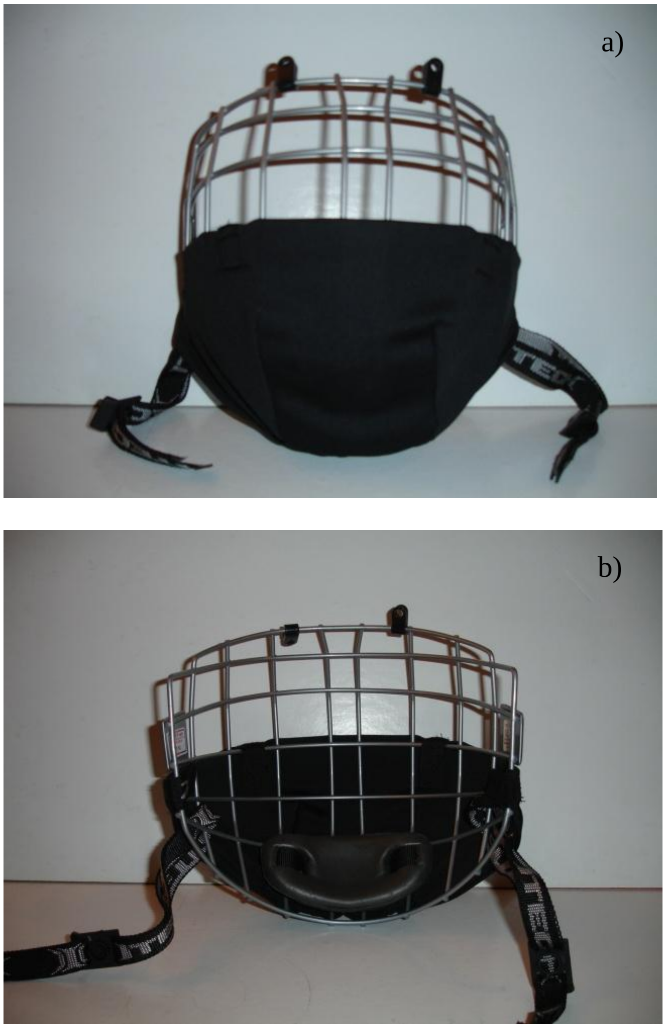


Figure 3. Facemask apparatus for restricted vision (RV). a) Front view of facemask in RV; b) Inside/player view from facemask in RV.

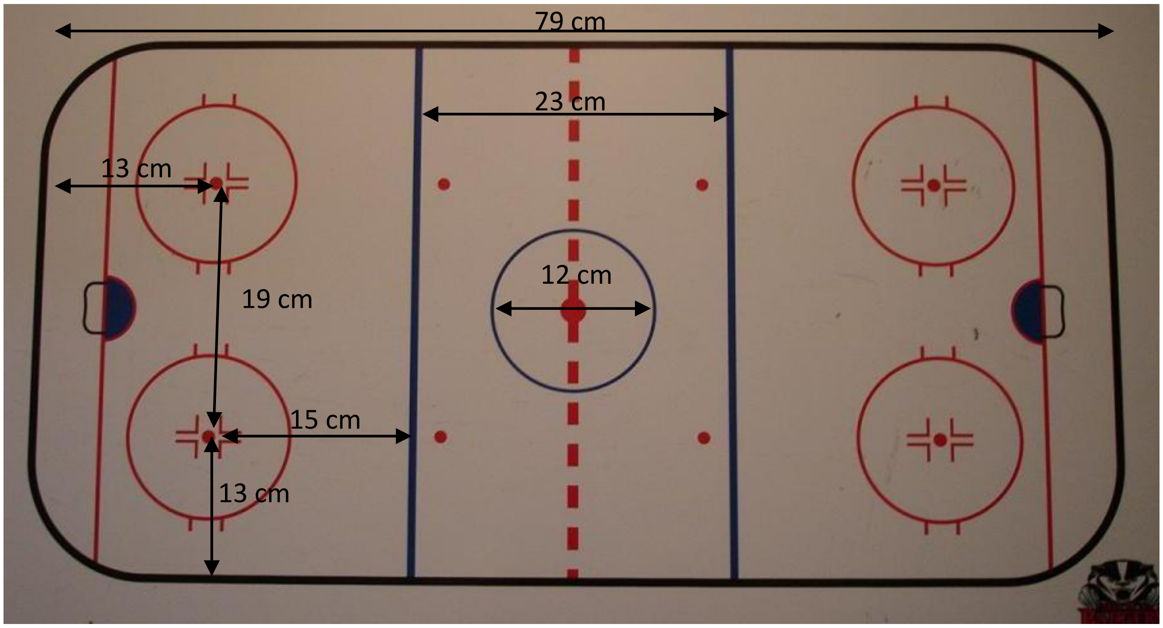


Figure 4. Puck Pad dimensions.

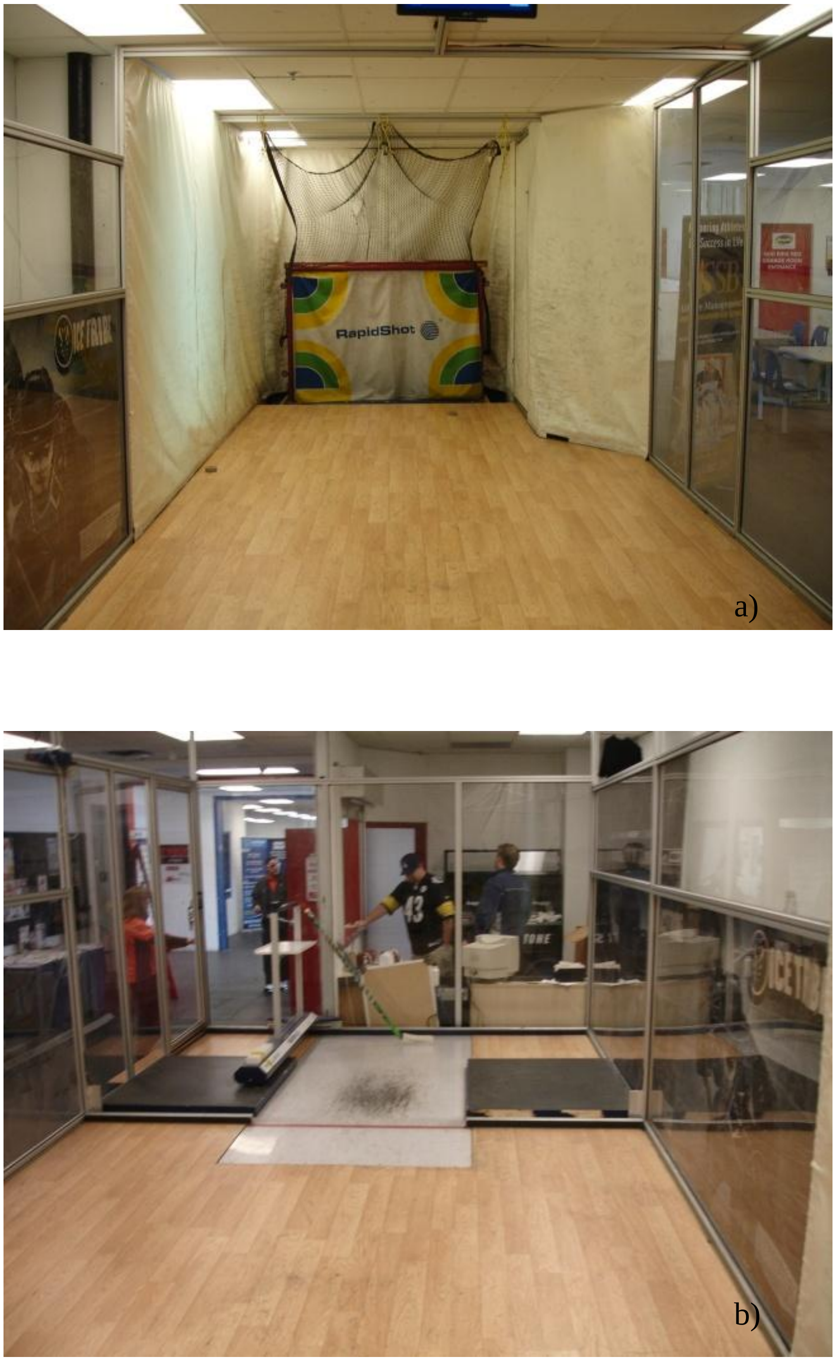


Figure 5. RapidShot™ Hockey Training System. a) Shooter's view; b) View from goal.

Corner target lamp

Figure 6. RapidShot™ goal target mat and corner lamps.

Figure 7. Foot standardization for shooting release.

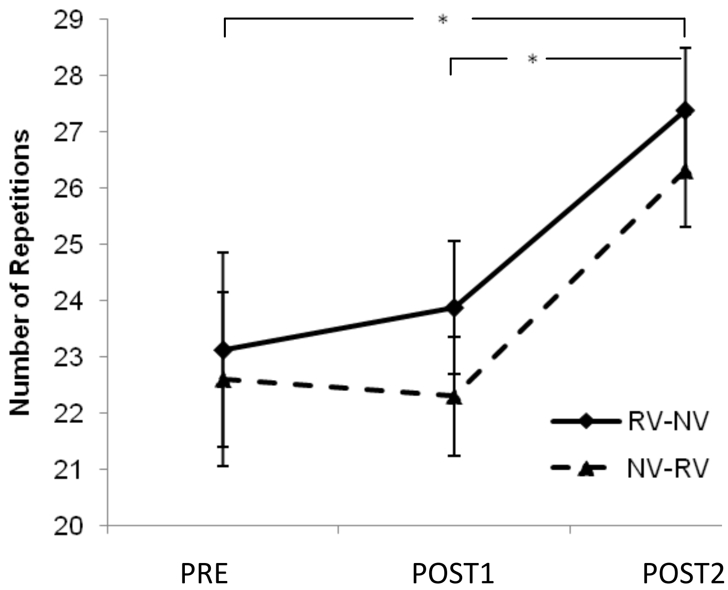


Figure 8. Simple SPC Normal Test Mean Scores by Training Group. Vertical lines depict standard errors of the means. * $p < 0.05$, SPC tests significant PRE-POST2 and POST1-POST2.

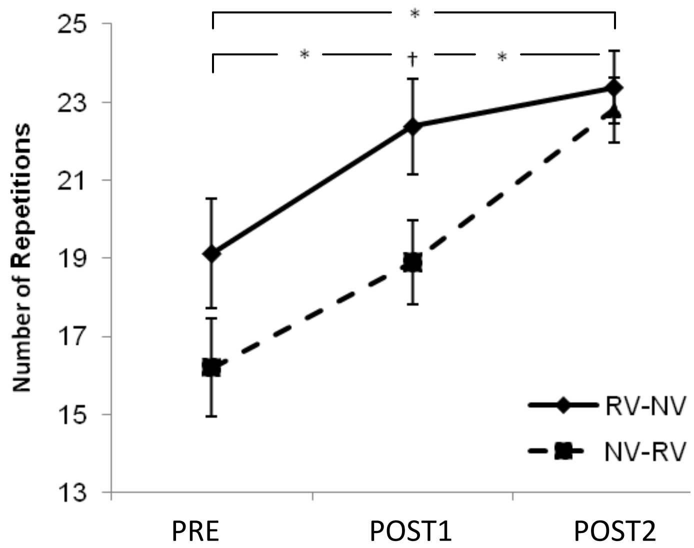


Figure 9. Simple SPC Restricted Test Mean Scores by Training Group. Vertical lines depict standard errors of the means. * $p < .05$, SPC tests significant PRE-POST1, POST1-POST2 and PRE-POST2. † $p < 0.05$, simple main effect between groups at POST1 test.

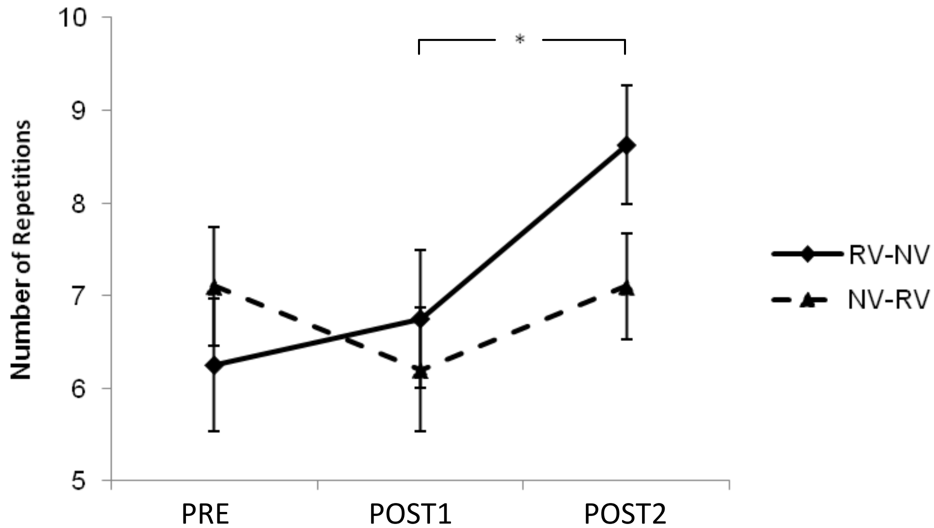


Figure 10. Complex SPC Normal Test Mean Scores by Training Group. Vertical lines depict standard errors of the means. * $p < 0.05$, SPC tests significant POST1-POST2.

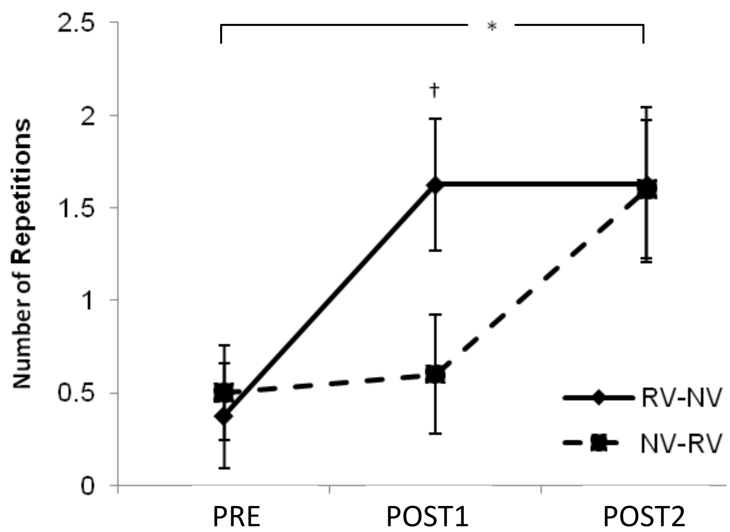


Figure 11. Complex SPC Restricted Test Mean Scores by Training Group. Vertical lines depict standard errors of the means. * $p < 0.05$, SPC tests significant PRE-POST2. † $p < 0.05$, simple main effect between groups at POST1 test.

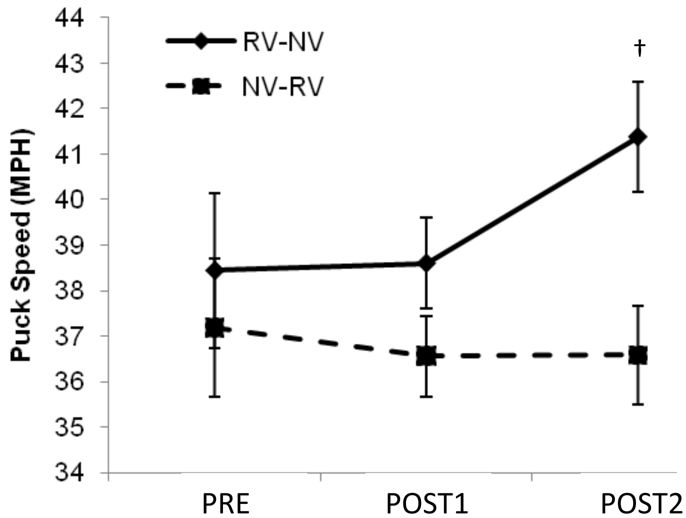


Figure 12. Shooting Speed Test Mean Scores by Training Group. Vertical lines depict standard errors of the means. † $p < 0.05$, simple main effect between groups at POST2 test.

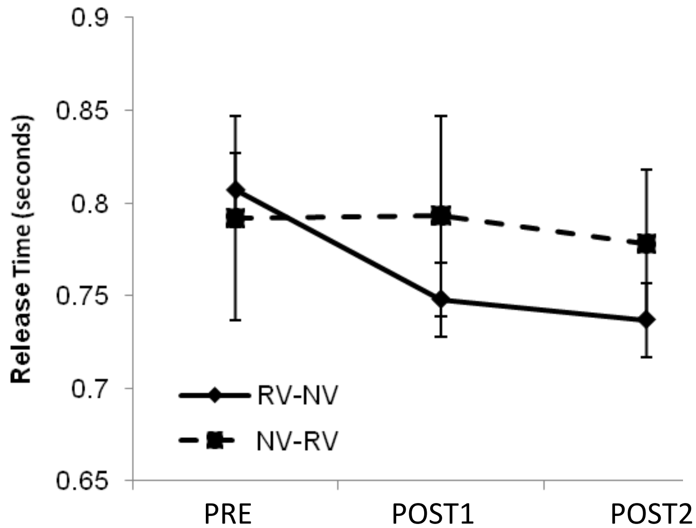


Figure 13. Shooting Release Time Mean Scores by Training Group. Vertical lines depict standard errors of the means.

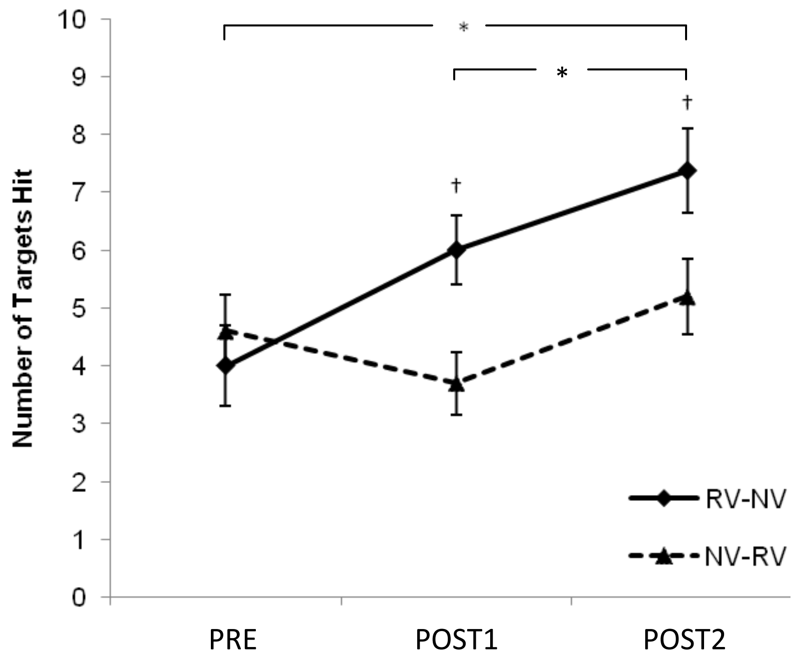


Figure 14. Shooting Accuracy Mean Scores by Training Group. Vertical lines depict standard errors of the means. * $p < 0.05$, main effect for accuracy PRE-POST2 and POST1-POST2. † $p < 0.05$, simple main effect between groups at POST1 test.

APPENDIX A- Glossary

Dominant hand: The hand/arm that is positioned approximately half way-three quarters the way up the hockey stick shaft depending on personal preference and shot type.

LSD- Least Significant Difference adjustment: Confidence interval adjustment used in statistical analysis.

Non-dominant hand: The hand/arm that is positioned on the butt end of the stick.

Normal Vision (NV) Training: Condition where there is full vision (central and periphery) during SPC training.

Normal Vision (NV) Test: SPC test conducted in full vision.

Restricted Vision (RV) Training: Condition where the periphery vision is blocked during SPC training.

Restricted Vision (RV) Test: SPC test conducted where periphery vision is blocked.

Shooting Series: The 16 shot series analyzed for the wrist shot test. 16 pucks were passed from the commercial device for a shot by the subject. The scores were interpreted from these 16 shots.

Shot release: Determined from the Rapidshot™ system from the time the puck initially passes through the infrared beam from the pass to the stick (player) to when the puck re-crosses the infrared beam after the puck has been shot. Measured in seconds.

SPC- Stickhandling and puck control: Maintaining puck possession within the stick's range of motion as the player is either stationary or moving. The blade is the portion of the stick that is used to control the puck.

APPENDIX B- Wrist Shot Velocities from Literature

Summary of Wrist Shot Velocities

Author (year)	N	Age (level)	Wrist Shot Type	Velocity MPH	KPH	MPS
Alexander et al., (1963)	11m	Pro	STANDING	63.1	101.5	28.2
			Skating	78.6	126.5	35.1
	7m	Amateur	STANDING	62.4	100.4	27.9
			Skating	70.5	113.5	31.5
	6m	Amateur	STANDING	58.7	94.5	26.2
			Skating	69.1	111.2	30.9
	6m	University	STANDING	54.3	87.4	24.3
			Skating	73.5	118.3	32.9
	30m	ALL	STANDING	59.6	95.9	26.6
			Skating	72.9	117.3	32.6
Alexander et al., (1964)	18m	Varsity	Skating	70.8	114.0	31.7
Cotton (1966)	17m	Varsity	STANDING	50.3	81.0	22.5
			Skating	55.9	90.0	25.0
Furlong (1968)		Pro	Skating	101.3	163.0	45.3
Nazar (1971)	26m	Varsity	STANDING-sb	51.6	83.1	23.1
			Skating-sb	56.6	91.1	25.3
			STANDING-cb	55.1	88.6	24.6
			Skating-cb	60.84	97.9	27.2

Author (year)	N	Age (level)	Wrist Shot Type	Velocity MPH	KPH	MPS
Chao (1973)		Adult	STANDING	82.0	132.0	36.7
			Skating	88.9	143.0	39.7
Roy (1974)		Jr. B	STANDING	39.8	64.0	17.8
			Skating	50.3	81.0	22.5
Naud (1975)	2m	Pro	STANDING	55.0	88.5	24.6
Sim (1978)	2m	Adult	STANDING	81.8	131.6	36.6
			Skating	88.6	142.6	39.6
	1m	Juvenile	Skating	54.5	87.7	24.4
Moyls (1981)	35m	Jr, Sr, Pro, Intermediate, Collegiate	STANDING	53.81	86.6	24.1
Leiter (2001)	12f	NWT	STANDING-4.5oz	46.2	74.4	20.5
			STANDING-5.0oz	44.7	72.0	19.9
			STANDING-5.5oz	44.3	71.3	19.7
			STANDING-6.0oz	43.9	70.7	19.5
Wu (2002)	10m	Varsity	STANDING-comp	44.6	71.8	19.9
			STANDING-med	43.7	70.3	19.5
			STANDING-stiff	43.9	70.6	19.6
			STANDING-all	44.1	70.9	19.7
	10m	Recreational	STANDING-comp	36.0	57.9	16.1
			STANDING-med	36.6	58.9	16.4
			STANDING-stiff	34.6	55.7	15.5
			STANDING-all	35.7	57.5	16.0

Author (year)	N	Age (level)	Wrist Shot Type	Velocity MPH	KPH	MPS
	10f	Varsity	STANDING-comp	31.1	50.1	13.9
			STANDING-med	31.3	50.4	14.0
			STANDING-stiff	29.1	46.9	13.0
			STANDING-all	30.5	49.1	13.6
	10f	Recreational	STANDING-comp	20.1	32.4	9.0
			STANDING-med	19.5	31.4	8.7
			STANDING-stiff	23.5	37.8	10.5
			STANDING-all	21.0	33.8	9.4
Worobets et al., (2006)	5m	Varsity	STANDING	59.9	96.5	26.8

Note. m = male; f = female; sb = straight blade; cb = curved blade; comp = composite hockey stick; med = medium stiffness stick; stiff = stiff hockey stick; NWT = National Women's Hockey Team; Different types of the slap and wrist shots in various studies. Adapted from "The Performance of the Ice Hockey Slap and Wrist Shots: The Effects of Stick Construction and Player Skill," by T. Wu, 2002, Master's Thesis, McGill University, Montreal, Quebec, Canada.

APPENDIX C- Informed Consent and Hockey Questionnaire

Applied Health Sciences

Department of
Physical Education & Kinesiology

On Ice Performance Laboratory
Faculty of Applied Health Sciences
Brock University, St.Catharines, ON, L2S 3A1, Canada

LETTER OF INFORMATION & INFORMED CONSENT

The Effects of Stickhandling and Puck Control (SPC) Training on Wrist Shot Performance Variables in Female Collegiate Ice Hockey Players

Overview of Research:

Sport-specific training development and evaluation in sport can be an extremely complex process. The use of sport-specific simulated activities has been touted as a beneficial training methodology; however few studies have successfully identified and quantified the effects of sport-specific training on performance measures as they relate to the on-ice sport, and specifically to women's ice hockey.

Despite the popularity of hockey, there has been limited research conducted for the development and training of stickhandling and puck control performance variables. In addition to understanding hockey game strategy, scoring success requires a player to develop the performance variables of shot accuracy, velocity and release time. However it has been suggested that to improve shooting skills, players would have to practice shooting for hours and in many cases, where shooting facilities and resources are not always available. Stickhandling and puck control is crucial in proper shooting as with inadequate control of the puck, can lead to lower quality shots taken or no shots at all. Therefore this study will investigate the effect of a SPC training regime on four stickhandling performance variables, namely puck control, wrist shot accuracy, velocity and release time. Secondly, this study will also examine if stickhandling and puck control training, while restricting the vision of the player's puck, stick and arms, will enhance the previously stated variables. It is proposed that training specific SPC movements repetitively may contribute to the development of the performance characteristics of shooting, due to the sport specific movements of stickhandling.

You are being asked to participate in the study titled "***The Effects of Stickhandling and Puck Control (SPC) Training on Wrist Shot Performance Variables in Female Collegiate Ice Hockey Players***. The study will be staged at 2 locations: the stickhandling training on individual Puck Pads (artificial ice) at the Seymour Hannah Sports and Entertainment Center in St. Catharines, Ontario, and the shooting assessments on the RapidShot™ Hockey Training System at The Wave Sports Center in Burlington, Ontario. Dr. Kelly Lockwood, who oversees the On Ice Performance Laboratory at Brock University, has extensive knowledge with the sport of ice hockey and will be supervising this study for MSc. candidate Briar Komenda.

Training Program Participants:

The purpose of the study is to examine the effects of stickhandling training on wrist shot velocity, accuracy and release (reaction time) as well as puck control. During week 1 (PRE), week 6 (POST1) and week 11 (POST2), athletes will complete a 1 hour stickhandling and shooting assessment. Stickhandling and puck control testing will require players to perform six, 20 second stickhandling and puck control tests on a rectangular piece (50cm x 90cm) of artificial ice. Actual shot testing will be conducted on a RapidShot™ Hockey Training System, located at The Wave Sports Center in Burlington, Ontario

During weeks 2 through 5 and 7 through 10, athletes will be asked to commit to two training sessions per week for 10 minutes each. Training sessions will take place at the Seymour Hannah Sports Complex in St. Catharines, Ontario, and scheduled before the regular morning hockey practices. The crossover design of this study requires the athletes to perform stickhandling under two different visual conditions, with each being 4 weeks in duration (8 training sessions).

Experimental Training (restricted vision-RV): During experimental RV training, athletes will have an opaque material screen fitted inside the lower portion of the helmet facemask (approximately up to the 4th horizontal rung on the helmet facemask) to limit the vision of the puck, stick and arms while performing the given training protocol. The material will have velcro straps that easily attach/detach to the players helmet through the cage rungs. The screen intends to promote the participants to keep their heads up and learn to feel the puck on the blade rather than looking at it. Athletes will be wearing their helmet, gloves and will use their own stick.

Non-Experimental Training (normal vision-NV): During the non-experimental NV training, participants will have full vision (no screen in facemask) and will follow the exact training protocol as the experimental group.

Participation in the research requires attendance at all training sessions. However provisions have been established if an athlete should miss a training session, due to illness, injury or conflict. A supervised make up session will be scheduled during the same week. All training and testing sessions will be under the supervision of the student principle investigator MSc. candidate Briar Komenda and/or Dr. Kelly Lockwood. Choosing to participate or not to participate will have no effect on your team standing. You may withdraw your participation from the study at any time. There will be no obligations or implications if you choose to withdraw.

Risks & Benefits of the Study:

Although it is not possible to predict all possible risks or discomforts that a participant may experience during a research study involving human activity, the intensity of the activities included in the above described study are not considered to be any more strenuous than a game of ice hockey. It will be the responsibility of the athlete to come to each training session prepared to exert herself, and this includes adequate fuel, hydration, rest and an enthusiastic attitude.

Participation in this study may potentially enhance the athlete’s stickhandling and puck control abilities as well as provide the player with additional stickhandling drills/patterns they can continue for individual skill development. This project has been reviewed by the Brock University Research Ethics Board and received ethics clearance (File # 08-173). Upon completion of the study, recommendations made for further training will also be discussed with individual athletes.

Participant's Consent:

In order to participate in the described study, this documentation must be read and signed. If participants are 18 years of age and older, they may complete the documentation themselves. Completed informed consents are mandatory for participation.

For participants to complete:

- In signing this form, I __________________________ *(Participant's Name),* acknowledge that, I have received an explanation about the nature of the study and its purpose. I give my permission ________________ *(Participant's Name)* to participate in the research described above at Brock University study conducted by MSc. candidate Briar Komenda and Dr. Kelly L. Lockwood.
  1. Participants can withdraw from the program at any time, without prejudice.
  2. Although we have strict policies in place to protect all participants in the program, accidents do happen. I understand that the instructors are qualified and will act in the best interest of the athletes.
  3. Participants will receive a copy of the Informed Consent Form and a summary of the research project upon completion.

Participant's Name: ________________ **Participant's Signature:** ___________________

The Principal Investigator, as indicated on this form, can be contacted to answer any questions regarding the experimental procedures.

MSc. Candidate Briar Komenda, Student Principal Investigator Tel: (905) 688-5550 X 4903
PEKN, Brock University, St. Catharines, ON L2S 3A1 E-mail: *briar.komenda@brocku.ca*

Dr. Kelly Lockwood, Supervisor Tel: (905) 688-5550 x 3092
PEKN, Brock University, St. Catharines, ON L2S 3A1 E-mail: *k.lockwood@brocku.ca*

Should you have concerns about the ethical conduct of the study, you may contact the Research Ethics Officer (reb@brocku.ca (905)688-5550, ext. 3035), who can provide answers to questions about the research participants rights.

Participant Information

- **Name**:_______________________________ **Height**:________

  Weight:________
- **Previous Team**:____________________ **Level**: Varsity IAA MAA MA

  Other:________
- **Years of hockey experience**: Rep____ Recreational/houseleague_____

  Total:_______
- **Age**:_____ **Date of Birth**: ____________
- **Shoots**: Left Right **Type of stick**: (ie. composite, Easton

  synergy)_______________
- **Primary Position Played (circle one)**: Forward Defense
- **Individual statistics from previous year**:

Games Played:_________ Goals:_______ Assists:________ Source:__________

- **How often did you practice shooting per week over the summer? (Circle one):**

  Never 1-2times 3-5times 6+

- **Have you ever used Rapidshot™? (Circle one):** Yes No

  If yes, how many times? ________________

APPENDIX D- Stickhandling Assessments

Test 1 (Simple- Side to side normal): The subject started the puck at the center of the Puck Pad (center circle dot marking) and was required to move the puck back and forth as many times as possible in 20 seconds, crossing both line markings on the Puck Pad. The distance between the lines was 23cm and this test was be used to assess primary puck control in a timed setting. If the puck did not cross one or both line markings, that specific trial did not count and the next complete trial was counted in the overall score.

Test 2 (Simple- Side to side cognitive): Test 2 was identical to test 1, however with the addition of a cognitive task to examine the expertise of the participant's primary SPC skills. The subject was instructed to count backwards by 3 number intervals from a random start number.

Test 3 (Simple -Side to side restricted): Test 3 was identical to test 1, however the subject would wear a material facemask apparatus to restrict the vision of the puck and the stick. The subject was able to look down to set the puck up initially, and then was asked to keep their head remaining up focusing on a spot at eye level for the test. If the puck were to come off the puck pad at anytime during the test, the investigator would signal this and the subject could look to bring the puck back on to the board and then continue with their head up. Knowledge of results were not given to the subjects when completing this task.

Test 4 (Complex- Figure 8 normal): The subject started the puck in the center of the Puck Pad and chose the direction of the figure 8 for the test. The investigator recorded both forehand/backhand and top/bottom for subsequent testing sessions. The puck had to follow the path of a horizontal “8” going around or touching both of the dots on the left and the right, as many times as possible in 20 seconds. If the puck did not go around or touch the dots, the trial did not count, and the next complete trial was counted in the overall score. This test assessed puck control during a more complex task. For all figure 8 tests, only one direction was tested and this was determined and recorded in the PRE test.

Test 5 (Complex- Figure 8 cognitive): Test 5 is identical to test 4, however with the addition of a cognitive task to again examine the expertise of the participant’s complex SPC skills. The subject was instructed to count backwards by 3 number intervals from a random start number.

Test 6 (Complex- Figure 8 restricted): Test 6 is identical to test 4, however the subject would wear a material facemask apparatus to restrict the vision of the puck and the stick. The subject was able to look down to set the puck up initially, and then was asked to keep their head remaining up focusing on a spot (something on tester) for the test. If the puck were to come off the puck pad at anytime during the test, the investigator would signal this and the subject could look to bring the puck back on to the board and then continue with their head up. Knowledge of results were not given to the subjects when completing this task.

APPENDIX E- Shooting and Stickhandling Data Recording Sheets

WRIST SHOT TEST

PRE POST1 POST2

DATE:______________________

SUBJECT NAME:____________________

 # OF TARGETS HIT________

AVERAGE SPEED______________

AVERAGE REACTION TIME___________________

POINTS_________________________

PEAK SPEED______________________

PEAK REACTION TIME__________________

ACCURACY

STICKHANDLING ASSESSMENT

EVALUATOR:__________ DATE:______________

SUBJECT:______________ STICK:________________ SHOOTS: L / R

PRE (WEEK 1)

RIGHT GRIP:_________________ LEFT GRIP:______________________

1. **SIDE TO SIDE:_________________________**

2. **SIDE TO SIDE (COGNITIVE):_______________________**

3. **SIDE TO SIDE (RESTRICTED):______________________**

FOREHAND BACKHAND TOP BOTTOM

4. **FIGURE 8’S:________________________**

5. **FIGURE 8’S (COGNITIVE): ____________________________**

6. **FIGURE 8’S (RESTRICTED):__________________________**

APPENDIX F- Additional RapidShot™ Information

Speed

Puck speed is determined as the puck passes through two infrared sensors providing a time measurement, which is combined with the constant distance, resulting in a calculation of speed (Linner & Linner, 2007). All speed scores are recorded in miles per hour (mph). By measuring speed, the goal contact times can be calculated for initiating the camera to begin analyzing the accuracy of the shot.

Release

Shot release is detected by sensors located in front of the shooting area on both sides emitting an infrared beam which intersects the puck path. The beam is first triggered when the pass crosses the line and stops after the puck is shot back through the beam. Shot release is evaluated in seconds.

A*ccuracy*

Shot accuracy is determined through a computer signal process indicating the puck location on the cover target map (Figure 6). Points for shot accuracy are assigned to either a yellow, green or blue score, with the blue receiving the most points, as task difficulty increases as greater precision is required. Blue, green and yellow targets earn 2, 1.5 and 1 point respectively towards the hit category factor which is then put in to a predetermined equation that generates points (Linner & Linner, 2007). No points are allocated for missed shots. Results are shown by percentage of hit rates per color and the average in each corner.

APPENDIX G- Motivational Questionnaire

POST1 / POST2 **CONDITION: RV_____ NV:______**

1. **I enjoyed doing this activity very much**

1	2	3	4	5	6	7
not at all true			somewhat true			very true

2. **This activity was fun to do.**

1	2	3	4	5	6	7
not at all true			somewhat true			very true

3. **I thought this was a boring activity**.

1	2	3	4	5	6	7
not at all true			somewhat true			very true

4. **This activity did not hold my attention at all**.

1	2	3	4	5	6	7
not at all true			somewhat true			very true

5. **I would describe this activity as very interesting**.

1	2	3	4	5	6	7
not at all true			somewhat true			very true

6. **I thought this activity was quite enjoyable.**

1	2	3	4	5	6	7
not at all true			somewhat true			very true

7. While I was doing this activity, I was thinking about how much I enjoyed it.

1 2 3 4 5 6 7
not at all true somewhat true very true

8. I put a lot of effort into this.

1 2 3 4 5 6 7
not at all true somewhat true very true

9. I didn't try very hard to do well at this activity.

1 2 3 4 5 6 7
not at all true somewhat true very true

10. I tried very hard on this activity.

1 2 3 4 5 6 7
not at all true somewhat true very true

11. It was important to me to do well at this task.

1 2 3 4 5 6 7
not at all true somewhat true very true

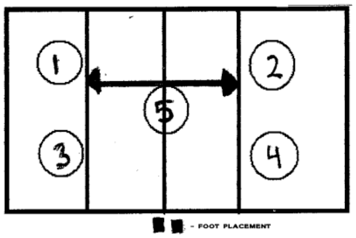
12. I didn't put much energy into this.

1 2 3 4 5 6 7
not at all true somewhat true very true

APPENDIX H- SPC Drill Patterns

SET A1 : SESSIONS 1-4

3 minutes

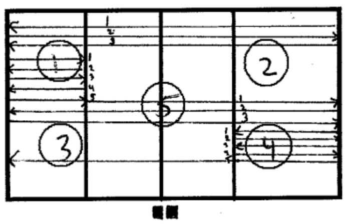


WARM UP STICKHANDLING

- 30 SECONDS - HEEL OF THE BLADE ONLY
- 30 SECONDS - TOE OF THE BLADE ONLY
- 30 SECONDS - MID OF THE BLADE ONLY

REPEAT TWICE

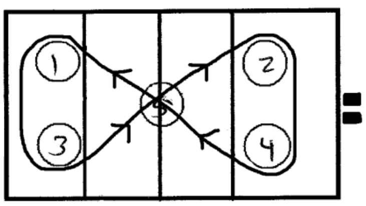
2 minutes



WIDE AND SHORT

- 3 WIDE STICKHANDLES FOLLOWED BY 5 SHORT STICKHANDLES. THE SHORT WIDTH STICKHANDLES WILL ALTERNATE LEFT AND RIGHT SIDES.

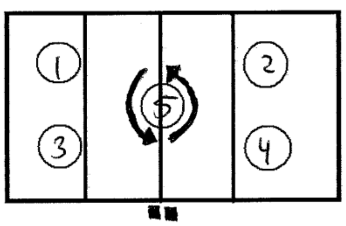
1:20 minutes



VERTICAL FIGURE EIGHT

- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION
- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION

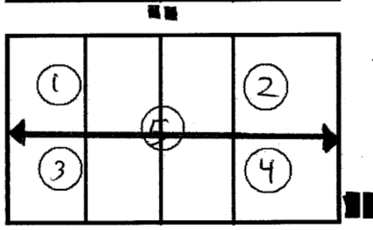
1:20 minutes



CENTER CIRCLE

- 20 SECONDS CLOCKWISE DIRECTION
- 20 SECONDS COUNTERCLOCKWISE DIRECTION
- 20 SECONDS CLOCKWISE DIRECTION
- 20 SECONDS COUNTERCLOCKWISE DIRECTION

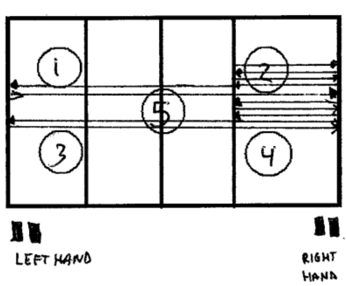
1:20 minutes



SIDE REACH

- 20 SECONDS FOREHAND SIDE REACH TOES
- 20 SECONDS BACKHAND SIDE REACH TOES
- 20 SECONDS FOREHAND SIDE REACH
- 20 SECONDS BACKHAND SIDE REACH

1 minute

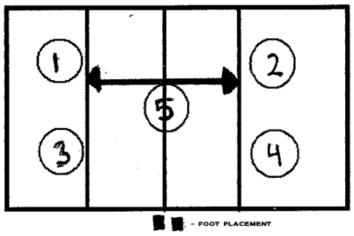


4 PLUS TOE PULL IN

- 4 SHORT STICKHANDLES IN 2/4 ZONE (RIGHT HAND) FOLLOWED BY 1 LONG STICKHANDLE TO THE 1/3 ZONE. THE PUCK IS THEN BROUGHT BACK TO THE STARTING POSITION WITH THE TOE OF THE BLADE AFTER THE LONG STICKHANDLE. REPEAT

SET A2 : SESSIONS 5-8

3 minutes

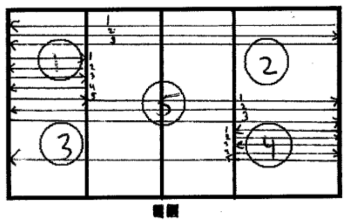


WARM UP STICKHANDLING

- 30 SECONDS - HEEL OF BLADE ONLY
- 30 SECONDS - TOE OF BLADE ONLY
- 30 SECONDS - MID OF BLADE ONLY

REPEAT TWICE

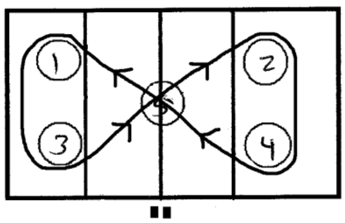
2 minutes



WIDE AND SHORT

- 3 WIDE STICKHANDLES FOLLOWED BY 5 SHORT STICKHANDLES. THE SHORT WIDTH STICKHANDLES WILL ALTERNATE LEFT AND RIGHT SIDES.

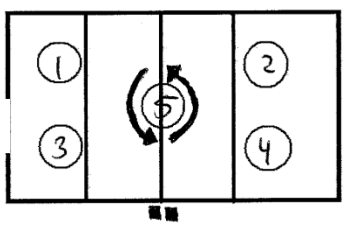
1:20 minutes



HORIZONTAL FIGURE EIGHT

- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION
- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION

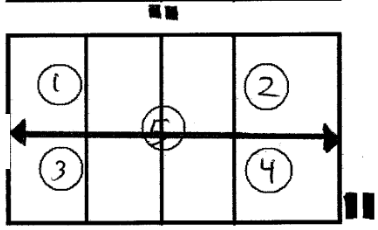
1:20 minutes



CENTER CIRCLE

- 20 SECONDS CLOCKWISE DIRECTION
- 20 SECONDS COUNTERCLOCKWISE DIRECTION
- 20 SECONDS CLOCKWISE DIRECTION
- 20 SECONDS COUNTERCLOCKWISE DIRECTION

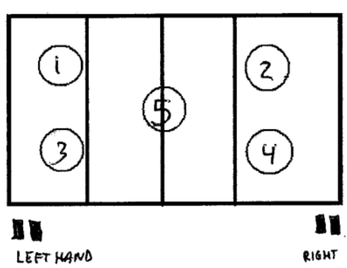
1:20 minutes



SIDE REACH

- 20 SECONDS FORHAND SIDE REACH
- 20 SECONDS BACKHAND SIDE REACH
- 20 SECONDS FOREHAND SIDE REACH
- 20 SECONDS BACKHAND SIDE REACH

1 minute

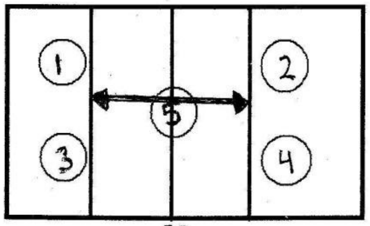


PUCK ROLL

- ROLL THE PUCK UP AND DOWN THE FRONT AND BACK OF THE BLADE WHILE KEEPING THE PUCK SPINNING.

SET B1 : SESSIONS 9-12

3 minutes

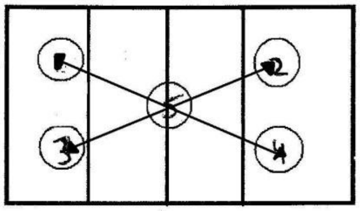


WARM UP STICKHANDLING

- 30 SECONDS - HEEL OF BLADE ONLY
- 30 SECONDS - TOE OF BLADE ONLY
- 30 SECONDS - MID OF BLADE ONLY

REPEAT TWICE

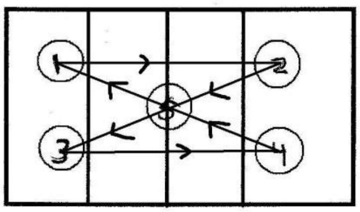
2 minutes



DIAGONAL

- STICKHANDLE 1 -> 3 FOR 30 SECONDS
- STICKHANDLE 2 -> 4 FOR 30 SECONDS
- STICKHANDLE 1 -> 3 FOR 30 SECONDS
- STICKHANDLE 2 -> 4 FOR 30 SECONDS

1:20 minutes

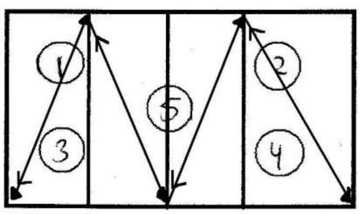


HOURGLASS

- MOVE PUCK HORIZONTALLY FROM 1-2 AND FROM 3-4 WHILE DIAGONAL FROM 2-3 AND 4-1.

- 20 SECONDS 1ST DIRECTION (1, 2, 3, 4)
- 20 SECONDS 2ND DIRECTION (2, 1, 4, 3)
- 20 SECONDS 1ST DIRECTION (1, 2, 3, 4)
- 20 SECONDS 2ND DIRECTION (2, 1, 4, 3)

1:20 minutes

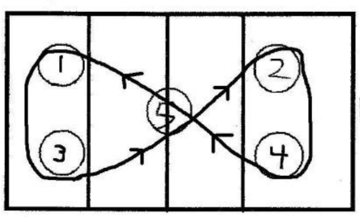


M - DRILL

- FOLLOW A "M" PATTERN USING TOE CONTROL.

- REPEAT FOR 1.20 MINUTES FOLLOWING THE SAME PATH TO THE ORIGINAL STARTING POSITION.

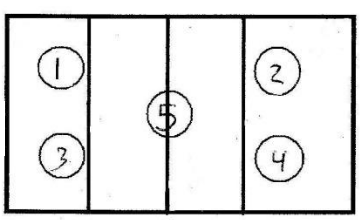
1:20 minutes



VERTICAL FIGURE EIGHT

- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION
- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION

1 minute



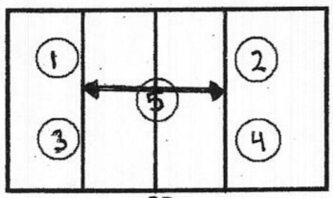
PUCK ROLL

- ROLL THE PUCK UP AND DOWN BOTH THE FRONT AND BACK OF THE BLADE WHILE KEEPING THE PUCK SPINNING.

SET B2 : SESSIONS 13-16

WARM UP STICKHANDLING

3 minutes

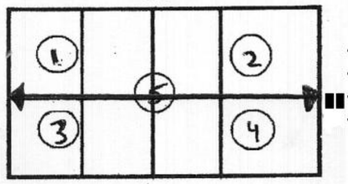


- 30 SECONDS - HEEL OF BLADE ONLY
- 30 SECONDS - TOE OF BLADE ONLY
- 30 SECONDS - MID OF BLADE ONLY

REPEAT TWICE

SIDE REACH

2 minutes

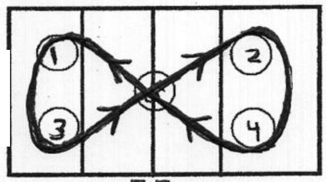


- 30 SECONDS FORHAND SIDE REACH
- 30 SECONDS BACKHAND SIDE REACH
- 30 SECONDS FOREHAND SIDE REACH
- 30 SECONDS BACKHAND SIDE REACH

LEFT HANDED

HORIZONTAL FIGURE EIGHT

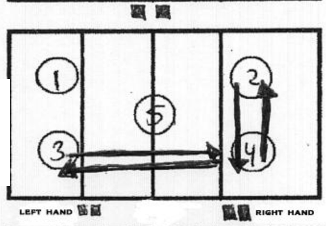
1:20 minutes



- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION
- 20 SECONDS FIRST DIRECTION
- 20 SECONDS SECOND DIRECTION

UP AND OUT TOE CONTROL

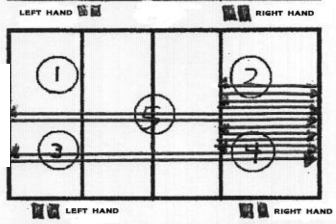
1:20 minutes



- PUSH PUCK TO TOP CIRCLE (DEPENDING ON HANDEDNESS) AND PULL BACK WITH TOE TO BOTTOM CIRCLE. THEN MOVE THE PUCK HORIZONTALLY ACROSS TO THE FAR CIRCLE AND BRING IT BACK WITH THE TOE TO THE STARTING POSITION. REPEAT.
- RIGHT HAND (CIRCLES: 4-2-4-3-4)
- LEFT HAND (CIRCLES: 3-1-3-4-3)

4 PLUS TOE PULL IN

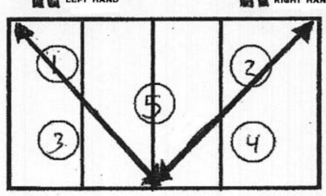
1:20 minutes



- 4 SHORT STICKHANDLES IN 2/4 ZONE (RIGHT HAND) FOLLOWED BY 1 LONG STICKHANDLE TO THE 1/3 ZONE. THE PUCK IS THEN BROUGHT BACK TO THE STARTING POSITION WITH THE TOE OF THE BLADE AFTER THE LONG STICKHANDLE. REPEAT.

"V" DRILL

1 minute



- MOVE THE PUCK UP AND BACK IN A "V" SHAPE FOR 1 MIUNUTE.

-MOVEMENT SHOULD BE CONTINUOUS.

APPENDIX I- Pilot Study

A pilot study conducted from 11 hockey games from the Brock University Women’s hockey team during the 2007-2008 season were observed to examine the frequency, type, and success of ice hockey shots. The location of shots and shot attempts were also recorded. For shooting and scoring analysis, two guides were used. A rink diagram was broken into 20 different areas (5 specific zones) in the offensive zone, from where shots could be generated from and a goal/net diagram, which was used to identify puck placement on net. A SWOT analysis consisting of: strengths, weaknesses, opportunities, threats (Panagiotou, 2003), was used to analyze the shooting and scoring performance. Results indicated that both positions, forward and defense, utilized the wrist, slap and backhand shots most frequently when shooting at the net, with the one timer wrist being the most successful. Weaknesses will only be discussed in this section as they have the most relevance to the current study being proposed. Forwards took most shots from the “house” area as defined by Dier (2007), and defense primarily shot in the area between the top of the circles to the offensive blueline. Shot on goal percentages for forward and defense players were 56.13 and 29.06 respectively, with only 8.197% and 2.00% of these shots being successful or resulting in a goal scored. A total of 29.7% of all shots taken were blocked boy both positions (defense 45/3% and forwards 21.5%) with the wrist, slap and one-timer slap being the most frequently blocked. Both forwards and defense produced similar results with miss percentages of 12.6 and 12.2 respectively with the wrist, slap and backhand combining for 76% of the missed shots. Potential rationale for missed shots may be due to the lack of control in shot accuracy when aiming for the corners. Players with their heads down during the play limit the vision of their teammates, goalie, open ice, opponents or the back of the net, thereby taking a chance on the shot and increasing the risk of missing the net or having the shot blocked. Blocked shots may also be due to players taking too long to shoot (too much time setting up the shot); allowing the other teams to gain body position in the shooting lane or the opposing player forcing the player to release the shot from an unnatural position. It was suggested that both positions need to increase the accuracy and percentage of shots that make it to the net to potentially score more goals. Increased puck possession and puck control should be implemented into practice to promote more game control. Players should also try and keep their heads up to monitor all environmental changes occurring during the game so they can respond appropriately.